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GEOLOGICAL SURVEY OF CANADA

WATER SUPPLY PAPER No. 316

GROUND-WATER RESOURCES
OF
EDWARDSBURGH TOWNSHIP,
GRENVILLE COUNTY,
ONTARIO

By

E. B. Owen



DEPARTMENT OF GEOLOGY
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1951

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area, and Figure 2 shows the positions of all wells for which records are available, together with the class of the well at each location.

GLOSSARY OF TERMS USED

Alluvium. Recent deposits of clay, silt, sand, gravel, and other material deposited in lake beds and in flood-plains of modern streams.

Aquifer. A porous bed, lens, pocket, or deposit of material that transmits water in sufficient quantity to satisfy pumping wells, flowing artesian wells, and springs.

Bedrock. Bedrock, as here used, refers to the consolidated deposits underlying the glacial drift. South of a line drawn between Midland, on Georgian Bay, and Kingston, the bedrock consists mainly of sedimentary rocks such as limestone, shale, slate, and sandstone; north of that line the bedrock consists chiefly of hard, crystalline, granitic rocks.

Contour. A line drawn on a map that passes through points that have the same elevation above mean sea-level.

Continental Ice-sheet. The great, broad ice-sheet that covered most of the surface of Canada many thousands of years ago.

Escarpment. A cliff or relatively steep slope separating two level or gently sloping areas.

Effluent Stream. A stream that receives water from a zone of saturation.

Flood-plain. A flat part in a river valley ordinarily above water, but covered with water when the river is in flood.

Glacial Drift. A general term that includes all the loose, unconsolidated materials that were deposited by the continental ice-sheet, or by waters associated with it. It includes till, deposits of stratified drift, and scattered boulders and rock fragments.

Several forms in which glacial drift occurs are as follows:

(1) End Moraine (Terminal Moraine). A more or less discontinuous ridge or series of ridges consisting of glacial drift that was laid down by the ice at the margin of a moving ice-sheet. The surface is characterized by irregular hills and undrained basins.

(2) Ground Moraine. A widely distributed moraine consisting of glacial drift deposited beneath an ice-sheet. The predominant material is till, which is clay containing stones. The topography may vary from flat to gently rolling.

(3) Kame Moraine. Assorted deposits of sandy and gravelly stratified drift laid down at or close to the ice margin. The topography is similar to that of an end moraine. Kame terraces are elongated deposits of this type laid down on the slopes of broad, flat-bottomed valleys.

(4) Drumlin. A smooth oval hill that has its long axis parallel with the direction of ice movement at that place. It is composed mainly of till.

(5) Esker. An irregular-crested ridge or series of discontinuous ridges of stratified drift deposited by a glacial stream that flowed beneath the continental ice-sheet or in deep crevasses within it. It is composed mainly of sand and gravel.

(6) Glacio-fluvial Deposits. Silt, sand, and gravel outwash deposited by streams resulting from the melting of the ice-sheet.

(7) Glacio-lacustrine Deposits. Clay, silt, and sand deposited in glacial lakes during the retreat of the ice-sheet. The clay deposits are commonly very distinctly stratified in layers a fraction of an inch to one or more feet in thickness; each layer is believed to represent deposition during one summer season and one winter season.

(8) Kame. An isolated mound or conical hill composed of stratified sand and gravel deposited in a crack or crevasse within the ice or in a depression along the ice front.

(9) Marine Deposits. Deposits laid down in the sea during the submergence that followed the withdrawal of the last ice-sheet. They consist chiefly of clay, silt, and sand, and have emerged beaches of sand and gravel associated with them.

(10) Shoreline. A discontinuous escarpment that indicates the former margin of a glacial lake or sea. It is accompanied by scattered deposits of sand and gravel located on former beaches and bars.

Ground Water. Sub-surface water in the zone of saturation below the water-table.

Hydrostatic Pressure. The pressure that causes water in a well to rise above the point at which it was first encountered.

Influent Stream. A stream that feeds water into a zone of saturation.

Impervious or Impermeable. Beds such as fine clays or shale are considered to be impervious or impermeable when they do not permit the perceptible passage or movement of ground water.

Pervious or Permeable. Beds are pervious or permeable when they permit the perceptible passage or movement of ground water, as, for example, porous sand, gravel, and sandstone.

Porosity. The porosity of a rock is its property of containing interstices or voids.

Pre-glacial Land Surface. The surface of the land as it existed before the ice-sheet covered it with drift.

Recent Deposits. Deposits that have been laid down by the agencies of water and wind since the disappearance of the continental ice-sheet; for example, alluvium in stream valleys.

Unconsolidated Deposits. The mantle or covering of loose, uncemented material overlying the bedrock. It consists of Glacial or Recent deposits of boulders, gravel, sand, silt, and clay.

Water-table. The upper limit of the part of the ground saturated with water. This may be near the surface or many feet below it. Water may be retained above the main water-table by a zone of impervious material; such water is said to be perched and its upper limit to be a perched water-table.

Wells. Holes sunk into the ground so as to obtain a supply of water. When no water is obtained they are referred to as dry holes. Wells yielding water are divided into four classes:

(1) Flowing Artesian Wells. Wells in which the water is under sufficient hydrostatic pressure to flow above the surface of the ground at the well.

(2) Non-flowing Artesian Wells. Wells in which the water is under hydrostatic pressure sufficient to raise it above the level of the aquifer, but not above the level of the ground at the well.

(3) Non-artesian Wells. Wells in which the water does not rise above the water-table or the aquifer.

(4) Intermittent Non-artesian Wells. Wells that are generally dry for a part of each year.

Zone of Saturation. The part of the ground, below a water-table that is saturated with water.

GENERAL DISCUSSION OF GROUND-WATER

Almost all the water recovered from beneath the earth's surface for both domestic and industrial uses is meteoric water, that is, water derived from the atmosphere. Most of this water reaches the surface as rain or snow. Part of it is carried off by streams; part evaporates either directly from the surface and from the upper

mantle of the soil or indirectly through transpiration of plants; the remainder infiltrates into the ground to be added to the ground-water supplies.

The proportion of the total precipitation that infiltrates from the surface into the zone of saturation will depend upon the surface topography and the type of soil or surface rock. More water will be absorbed in sandy or gravelly areas, for example, than in those covered with clay. Surface run-off will be greater in hilly areas than in those that are relatively flat. In sandy regions where relief is great, the first precipitation is absorbed and run-off only commences after continuous heavy rains. Light rains falling upon the surface of the earth during the growing season may be wholly absorbed by growing plants. The quantity of moisture lost through direct evaporation depends largely upon temperature, wind, and humidity. Ground water in areas overlain by pervious material may be recharged by influent streams carrying run-off from areas overlain by relatively impervious material.

Because of the large consumption of ground water in settled areas, it may seem surprising that precipitation can furnish and adequate supply. However, when it is borne in mind that a layer of water 1 inch deep over an area of 1 square mile amounts to approximately 14,520,000 imperial gallons, and that the annual precipitation in this region, for example, is about 30 inches, it will be seen that each year some 435,600,000 imperial gallons of water falls on each square mile. Although it would be impossible to determine the annual recharge of the ground-water supply of the area, if it were assumed that only 10 per cent of the total precipitation, namely 43,560,000 gallons, is contributed to the zone of saturation, it will be seen that the annual recharge for the entire area would be a very large volume. The annual consumption

of water in all areas investigated is not known, but an estimate for some restricted areas, based on per capita consumption, shows it to be only about one-tenth of the annual recharge as estimated above.

In most regions of the world where precipitation is effective there is an underground horizon known as the ground-water level or water-table, which is the upper surface of the zone of saturation. The water-table commonly is a subdued replica of the surface topography. The water that enters from the surface into the unconsolidated deposits and rocks of the earth is drawn down by gravity to where it reaches the zone of saturation or comes in contact with a relatively impervious layer. Such a layer may stop further downward percolation, resulting in perched water and creating a perched water-table. If a water-table is at or near the surface, there will be a lake or swamp; if it is cut by a valley, there will be a stream in the valley. The terms influent and effluent are used with reference to streams and their relation to the water-table. An influent stream flows above the water-table and feeds water into the zone of saturation; an effluent stream flows at or below the water-table and receives water from the zone of saturation. An effluent stream may become influent and eventually dry up if the water-table is lowered sufficiently. The ground water in the zone of saturation is almost constantly on the move percolating towards some point of discharge, which may be a spring or a pumping well.

All rocks and soils are to some degree porous, that is, the individual grains or particles of which they are composed are partly surrounded by minute interstices or open spaces that form the receptacles and conduits of ground-water. In most rocks and soils ~~the interstices are connected and large enough for the water to move~~ from one opening to another. In some rocks or soils, however, they are largely isolated or too small to allow movement of water. The

porosity of a material varies directly with the size and number of its interstices, which in turn depend chiefly upon the size, shape, arrangement, and degree of assortment of the constituent particles. Horizons within the earth's crust of fine-grained rock such as shale, limestone or dolomite, or unconsolidated clay or silt, may have such small interstices that the contained water will not flow readily and wells penetrating them may derive little or no water from them. Such horizons are considered impervious. Beds of more coarse-grained materials such as sand, gravel, or sandstone have greater porosity and readily yield their waters to wells. They are called water-bearing beds or aquifers. A clean water-bearing gravel is one of the best sources of water. This is true whether the water is derived from the zone of saturation or from a bed of gravel confined above, between, or below beds of less pervious material.

Consolidated rocks usually considered to be impervious may sometimes produce water in relatively good supply from openings within them of primary or secondary origin. Those of primary origin, original interstices, were created when the rocks came into existence as a result of the processes by which they were formed; e.g. bedding planes, and intergranular spaces. Secondary interstices comprise joints and other fracture openings, solution openings, and openings produced by several processes of minor importance, such as the work of plants and animals, mechanical erosion, and recrystallization; all of these involve movement of a type that acted after the consolidation of the rock. The most important interstices with respect to water supplies are the original interstices, next to them are the fracture and solution openings.

The most common wells and those that in drift-covered areas yield the largest aggregate supply of ground water are water-table wells. These are wells that derive their water from the zone of

saturation. Many shallow wells become dry during the late summer and winter, or during periods of extreme drought. In most cases this is due to the lowering of the water-table below the bottom of the well. The grouping together of a number of water-table wells within a limited area will also lower the yield of any one of the wells. This is especially true of water-producing formations of low permeability. When a well penetrates an aquifer confined by impervious beds, water will be forced upward by hydrostatic pressure exerted at the point where the well enters the aquifer. If the hydrostatic pressure is great enough to force the water to or above the surface, a flowing well is formed.

Springs are formed where the water-table, or some water-bearing aquifer, outcrops at the surface of the ground. The water emerging from water-table springs is free-running water flowing down the gradient of the water-table. In many cases these springs occur as slow seeps along the steeper slopes of stream valleys. A large number in one area could maintain a swamp. A group of permanent springs occurring in one area could provide sufficient water to maintain a lake or form the source of a stream.

GENERAL DISCUSSION OF GROUND-WATER ANALYSIS

The mineral content of ground water is of interest to many besides those industries seeking water of specific quality. Both the kind and quantity of mineral matter dissolved in natural water depend upon the texture and chemical composition of the rocks with which the water has been in contact. Pollution is caused by contact with organic matter or its decomposition products. Analyses of well waters for mineral content are made by the Mines Branch, Department of Mines and Technical Surveys, Ottawa.

In any given area, an attempt is made to secure samples of water representative of all major aquifers. The quantities of the

various constituents for which tests are made are given as "parts per million", which refers to the proportion by weight of each constituent in 1,000,000 parts of water.

The following mineral constituents are those commonly found in natural waters in quantities sufficient to have a practical effect on the value of the waters for ordinary uses:

Silica (SiO_2) may be derived from the solution of almost any rock-forming silicate, although its chief source is the feldspars. It is commonly determined in the analysis of water for use in steam boilers, as silica is classed as an objectionable encrustant.

Calcium (Ca). The chief source of calcium dissolved in ground water is the solution of limestone, gypsum, and dolomite. The common compounds of calcium are calcium carbonate (CaCO_3) and calcium sulphate (CaSO_4), neither of which has injurious effects upon the consumer, but both of which cause hardness and, the former, boiler scale.

Magnesium (Mg). The chief source of magnesium in ground water is dolomite, a carbonate of calcium and magnesium. The sulphate of magnesium (MgSO_4) combines with water to form Epsom-salts ($\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$), and renders the water unwholesome if present in large amounts.

Sodium (Na) is found in all natural waters in various combinations, though its salts constitute only a small part of the total dissolved mineral matter in most waters in humid regions. Sodium salts may be present as a result of pollution by sewage, or of contamination by sea water either directly or by that enclosed in sediments of marine origin. Moderate quantities of these salts have little effect upon the suitability of a water for ordinary uses, but water containing sodium in excess of about 100 parts per million must be used with care in steam boilers to prevent foaming. Waters containing large quantities of sodium salts are injurious to crops and are, therefore, unfit for irrigation. The quantity of sodium salts

may be so large as to render a water unfit for nearly all uses.

Potassium (K), like sodium, is derived originally from the alkaline feldspars and micas. It is of minor significance and is sometimes included with sodium in a chemical analysis.

Iron (Fe) is almost invariably present in well waters, but rarely in large amounts. Salts, or compounds, of iron are dissolved from many rocks as well as from iron sulphide deposits with which the ground water comes in contact. It may also be dissolved from well casings, water pipes, and other fixtures in quantities large enough to be objectionable. Upon exposure of the water to the atmosphere, dissolved iron separates as the hydrated oxide that imparts a yellowish brown discoloration. Excessive iron in water causes staining on porcelain or enamelled ware and renders the water unsuitable for laundry purposes. Water is not considered drinkable if the iron content is more than 0.5 parts per million.

Sulphates (SO_4). Deposits of gypsum ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$) are the principal source of sulphates dissolved in ground water; soluble sulphates, chiefly of magnesium and sodium, are other sources. Sulphates cause permanent hardness in water and form injurious boiler scale. Sodium and magnesium sulphates are laxative when present in quantities of more than 900 parts per million.

Chloride (Cl) is derived chiefly from organic materials or from marine rocks and sediments. It occurs usually as sodium chloride and less commonly as calcium chloride and magnesium chloride. Sodium chloride is a characteristic constituent of sewage and a locally abnormal amount suggests pollution. However, because chlorides may be derived from many sources, such abnormal quantities should not, in themselves, be taken as positive proof of pollution. Chlorides impart a salty taste to water if they are present in excess of 300 parts per million.

Nitrates (NO_3) are of minor importance in the study of ground water. Relatively large quantities in a water may represent

pollution by sewage, or drainage from barnyards, or even from fertilized fields. It is recommended that a bacteriological test be made of water showing an appreciable nitrate content if it is to be used for domestic purposes.

Carbonate (CO_3) forms a large percentage of the solid compounds held in solution by the average ground water. The two chief sources are the decomposition of feldspars and the solution of limestone by water carrying carbonic acid in solution, which is the primary agent in rock decomposition. They are indicated in the table of analyses as alkalinity. Calcium and magnesium carbonates cause hardness in water, whereas sodium carbonate causes softness.

Bicarbonate (HCO_3). Carbon dioxide dissolved in water renders the insoluble calcium and magnesium carbonates soluble as bicarbonates. Boiling reverses the process by changing the bicarbonates into insoluble carbonates, which form a coating on the sides of cooking utensils.

Total Dissolved Solids (Residue on Evaporation). The term is applied to the residue obtained when a sample of water is evaporated to dryness. Waters are considered high in dissolved mineral solids when they contain more than 500 parts per million, but may be accepted for domestic use up to that point if no better supply is available. Residents, accustomed to the waters, may use waters that carry well over 1,000 parts per million of total dissolved solids without inconvenience, although persons not used to such highly mineralized waters would find them objectionable.

Hardness is a condition imparted to waters chiefly by dissolved calcium and magnesium compounds. It here refers to the soap-destroying power of water, that is, the power of the water

first to use a certain amount of soap to precipitate the above compounds before a lather is produced. The hardness of water in its original state is its total hardness. Permanent hardness remains after the water has been boiled, and is caused by mineral salts that cannot be removed from solution by boiling. It can be reduced by treating the water with natural softeners, such as ammonia or sodium carbonate, or with many manufactured softeners. Temporary hardness can be eliminated by boiling, and is due to the presence of bicarbonates of calcium and magnesium. Waters containing larger quantities of sodium carbonate than of calcium and magnesium compounds are soft, but if the latter compounds are more abundant the water is hard. The following table¹ may be used to indicate the degree of hardness of a water:

<u>Total Hardness</u>	
<u>Parts per million</u>	<u>Character</u>
0-50	Very soft
50-100	Moderately soft
100-150	Slightly hard
150-200	Moderately hard
200-300	Hard
300 and over	Very hard

¹
Thresh, J. C., and Beale, J. F.; The Examination of Waters and Water Supplies, p. 21, London, 1925.

PART II

EDWARDSBURGH TOWNSHIP, GRENVILLE COUNTY, ONTARIO

Physical Features

Edwardsburgh township is in the southeast part of Grenville county, and has an area of approximately 112 square miles. The township extends along the northwest side of the St. Lawrence River from a point approximately 1 mile east of the town of Prescott to $1\frac{1}{2}$ miles east of the town of Cardinal. Cardinal, the largest community in the township, lies about 118 miles west of Montreal.

The topography of Edwardsburgh township is that of a flat sand plain upon which are scattered numerous, large, elongated ridges of clay till and smaller knolls and hills of kame sand. The general trend of the topography varies from south 10 degrees west to south 30 degrees west. Bedrock, which consists of flat-lying Ordovician sedimentary formations, is reflected in the surface wherever the overburden is thin. A poorly marked divide between the basins of Ottawa and St. Lawrence Rivers crosses the south part of the township in an east-west direction. Near Cardinal, the divide is only 2 miles from the St. Lawrence River, and farther west in the township the distance is about 3 miles.

The large area north of the divide is drained by South Nation River, which, together with its numerous small tributaries, crosses the north half of the township in a northeast direction. The drop in South Nation River between the Canadian Pacific Railway bridge west of Spencerville and the bridge at Hyndman, a distance of 8 miles, is 22.2 feet. This indicates an average gradient across the township of 2.8 feet a mile.

The township as a whole has a relief of more than 125 feet. The highest elevation is in the northwest part where an altitude of more than 375 feet is attained. The lowest part is on the St. Lawrence River in the southwest corner of the township where the altitude is less than 250 feet above sea-level.

Graphs have been prepared depicting the monthly precipitation from 1947 to the end of 1950, as measured at various meteorological stations

in the area about Edwardsburgh township, and the fluctuations in the water-table, as measured at an observation well near the town of Morrisburg for the same period. The latter was provided through the courtesy of the Ontario Department of Mines. From these graphs, it will be noted that, during the months when the ground is not frozen, the elevation of the water-table depends, to a large extent, on the amount of precipitation falling upon the area. In general, the lowest amount of precipitation occurs_during the months of August and September, and it is during that period that the water-table shows a steady decling, commonly reaching its lowest point in October.

In the subsequent months, there are periods of considerable precipitation, but, because the frozen condition of the ground prevents downward percolation of water, and the fact that a great deal of the precipitation is in the form of snow, the water-table remains low during the winter months and does not commence to rise until the end of February.

The highest elevation of the water-table is reached during May and June. This is normally due to the supplementing of the regular precipitation with water from melting snow and ice accumulated on the surface during the winter months.

X
Precipitation in Inches

Station	Year	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
Brockville	1950	6.0	3.6	4.6	2.5	1.8	3.4	3.2	1.3	1.3	2.8	5.8	3.7	42.3
	1949	3.6	3.3	2.8	4.7	1.8	1.4	3.2	5.6	4.4	1.8	4.5	3.4	38.5
	1948	3.1	3.0	4.6	2.6	3.2	3.8	3.5	1.8	0.6	2.9	5.4	3.6	38.1
	1947	4.7	2.4	5.5	2.1	7.0	4.5	6.0	1.6	4.5	1.0	3.7	3.1	46.1
	1946	3.4	2.7	1.4	2.1	4.3	1.8	2.9	2.0	3.2	5.7	3.3	4.9	37.7
Donville	1950	3.8	3.2	3.7	2.7	2.0	1.1	4.3	4.1	-	1.8	4.5	3.1	34.1
	1949	2.6	3.3	2.6	5.0	2.2	1.2	2.2	3.4	3.3	1.7	3.3	3.3	34.1
	1948	-	-	-	-	2.7	2.9	3.5	2.3	0.2	2.7	4.2	2.8	-
	1947	-	-	-	-	-	-	-	-	-	-	-	-	-
	1946	-	-	-	-	-	-	-	-	-	-	-	-	-
Kemptville	1950	3.8	3.6	3.6	3.0	1.8	1.3	3.0	3.9	1.0	1.9	4.4	2.6	33.9
	1949	3.2	3.0	2.1	4.6	2.8	0.6	2.2	4.8	3.2	1.7	3.5	2.4	34.6
	1948	1.4	2.1	3.3	2.1	2.9	3.1	3.4	4.9	0.6	2.9	4.1	3.5	32.3
	1947	3.6	1.7	5.5	1.9	4.0	3.4	7.4	2.3	5.2	0.3	2.7	1.5	39.5
	1946	2.9	1.5	1.2	2.3	3.8	1.6	2.0	1.6	2.7	5.0	3.5	3.6	31.9
Morrisburg	1950	4.5	3.7	3.8	2.8	1.3	1.8	4.9	5.1	1.4	2.0	5.9	4.4	41.6
	1949	3.2	4.0	2.6	4.2	2.6	0.8	1.9	1.9	5.0	2.0	3.7	3.1	35.0
	1948	1.6	3.3	3.8	2.4	2.8	3.5	3.1	3.6	0.1	3.0	5.1	3.6	35.9
	1947	5.3	3.0	5.9	2.1	5.6	5.8	7.7	1.6	5.8	0.6	3.7	3.1	50.1
	1946	3.0	2.0	1.8	2.6	2.6	1.6	1.5	1.5	4.5	6.4	3.8	4.3	37.6

X Extracts from the 'Monthly Weather Map', Meteorological Service, Dominion of Canada.

WATER-TABLE ELEVATIONS
(Feet above sea-level)

Name: W. T. Richardson
Address: R R - 1 Morrisburg, Ontario
Well type: dug
Well depth: 25 feet (Aug. 22, 1950)
Well elevation: 248.0 feet above sea-level
Material from which ground water derived: clay till

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1947	235.4	237.2	234.9	237.4	240.1	242.8	239.0	237.9	233.7	236.1	234.9	236.8
1948	234.3	-	237.4	236.4	235.7	237.5	233.8	-	230.9	229.2	230.3	230.6
1949	230.6	230.7	230.1	235.3	237.4	235.3	233.4	231.9	230.5	230.7	230.5	229.6
1950	-	-	-	234.7	236.7	-	-	234.3	233.9	-	233.4	-

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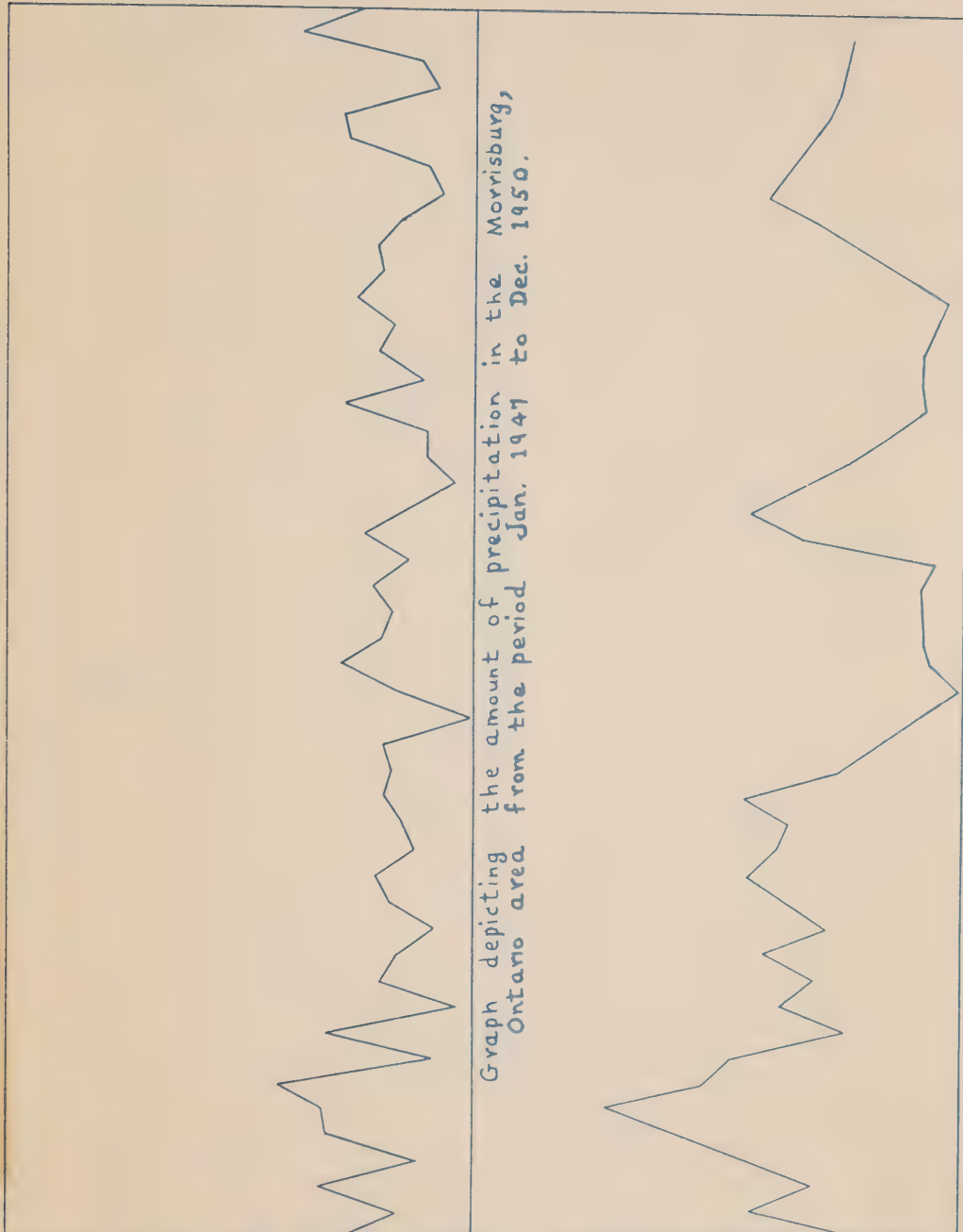
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PRECIPITATION IN INCHES

ELEVATIONS OF WATER TABLE

(feet above sealevel)

8.0
6.0
4.0
2.0
0.0
242
240
238
236
234
232
230



Graph depicting the amount of precipitation in the Morrisburg, Ontario area from the period Jan. 1947 to Dec. 1950.

J. F. M. A. M. J. J. A. S. O. N. D. J. F. M. A. M. J. J. A. S. O. N. D. J. F. M. A. M. J. J. A. S. O. N. D.
1947 1948 1949 1950

Graph depicting the fluctuations in the water table in the Morrisburg, Ontario area from the period Jan. 1947 to Dec. 1950. (Courtesy of the Ont. Dept. of Mines)

Geology

Bedrock Formations. The township, which is located within the Ottawa - St. Lawrence Lowland, is underlain by Palaeozoic rocks of Ordovician age. In most cases, the rocks are flat-lying or gently undulating. The general dip is extremely low and in a northwest direction.

Table of Formations¹

Era	Period	Sub. Epoch	Formation	Thickness (Feet)	Lithology
Palaeo- zoic	Ordovician	Trenton and Black River	Ottawa	690-700	Limestone with a little shale, some sand at base
		Disconformity			
		Chazy	St. Martin Rockcliffe	20-155 150-165	Impure limestone Shale with sand- stone lenses
	Disconformity				
	Ordovician or Cambrian	Beekman- town	Oxford	240(±)	Dolomite with a little shale at top; interbedded sandstone and dolomite
			March	30(+)	
			Nepean	Up to 500	Sandstone
Great Unconformity					
Precam- brian (Archa- ean)?			Grenville		Crystalline limestone, quartzites, and metamorphic rocks; associated granite and granite-gneiss

¹ Wilson, A.E.: Geology of the Ottawa - St. Lawrence Lowland, Ontario and Quebec; Geol. Surv., Canada, Mem. 241, p. 9 (1946).

The March formation underlies a small area in the southwest part of the township in the vicinity of Donville station on the Canadian Pacific railway. The remainder of the township is underlain by the succeeding Oxford formation, except for an extremely small area along the east boundary in the northeast part of the township, which is underlain by the Rockcliffe. The Precambrian rocks are represented by one small outcrop of white quartzite located in lot 33, con. IV.

Overburden. The types of overburden occurring in the township, classified according to their origin and arranged in order of their deposition from oldest to youngest, are as follows: glacial till, glacio-fluvial material, and marine beds. Recent deposits are relatively scarce and unimportant.

Glacial materials in the township occur chiefly as ground moraine. In most instances they are completely buried beneath glacio-fluvial material and marine sediments and, accordingly, are only encountered during excavating or drilling operations, although in some localities they outcrop as elongated hills and ridges of clay till. Many of these structures appear to be the upper parts of half-buried drumlins, with their long axes parallel to the direction of the last ice movement. They often have the appearance of 'islands' of clay till in a 'sea' of marine sand and clay. Thin layers of till reworked by invading marine waters occur on some of the higher ground. They are frequently associated with accumulations of large boulders.

Glacio-fluvial material in the form of kames, is extensive throughout Edwardsburgh township. The kames occur as scattered knolls and irregular ridges of sand and fine gravel, the relief of which has been considerably lowered by the planing action of the waves. In most instances, the kame material directly overlies clay till or bedrock.

The invasion and subsequent withdrawal of the Champlain Sea, which followed the retreat of the ice-sheet in the region, formed various deposits of marine origin. The most extensive of these in Edwardsburgh township are the beds of sand and clay that occur in the flat areas between the higher ridges of clay till and kame material.

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Marine clay is extensive throughout the township, but in most instances is covered by a layer of marine sand of various thicknesses, and except for a few small areas, one in lot 20, con. VIII, and others in lots 25 to 30, con. I, can only be seen along the banks and in the bottoms of small creeks.

Marine sand covers a large part of Edwardsburgh township. It appears to overlies all other unconsolidated material in the township with the exception of the Recent. The thickness of the marine sand is not great, varying generally from a few inches to a few feet.

Alluvial clay, silt, and sand occur along the flood plain of South Nation River between the community of Ventnor and the point where the river leaves the township. These materials may overlies either bedrock, clay till, or marine clay. They are shallow beds, considered to be derived mainly from the reworking of glacial drift.

Dune sand occurs locally in Edwardsburgh township. It is usually concentrated on the east side of kame deposits, which are the source of much of the material. The material consists of a fine, white sand that is useless for farming. These deposits are not considered important as sources of ground water.

Variations in the thickness of drift throughout the township were determined in many localities as a large number of the recorded wells were reported to have encountered bedrock.

The following table indicates the minimum and maximum thicknesses of drift in several localities, as indicated by the recorded wells:

Concession	Lot	Minimum and Maximum Thickness of Drift (feet)	Concession	Lot	Minimum and Maximum Thickness of Drift (feet)
1	1	21 ^x - 35 ^x	4	1	30 ^x - ?
1	4	24 ^x - 30 ^x	4	4	7 ^x - 35 ^x
1	7	29 - ?	4	7	28 ^x - 29 ^x
1	10	0 ^x - 6 ^x	4	10	36 - ?
1	13	22 - ?	4	19	4 ^x - ?
1	16	16 - ?	4	22	9 ^x - ?
1	19	50 - ?	4	25	10 - ?
1	22	25 - ?	4	28	18 - ?
1	28	22 ^x - 26 ^x	4	34	78 ^x - ?
1	31	0 ^x - 35 ^x	5	2	29 - ?
1	34	12 ^x - ?	5	5	24 ^x - ?
2	5	10 - ?	5	8	40 ^x - ?
2	11	20 ^x - 49 ^x	5	11	22 - ?
2	14	13 - ?	5	14	17 - ?
2	17	21 - ?	5	17	16 - ?
2	20	25 - ?	5	20	5 ^x - ?
2	23	10 - ?	5	29	18 - ?
2	35	9 - ?	5	32	7 ^x - 14 ^x
3	3	20 - ?	6	3	5 ^x - 23
3	6	40 ^x - ?	6	3	29 ^x - 30 ^x
3	9	43 - ?	6	9	23 - ?
3	12	8 ^x - 24	6	12	17 ^x - ?
3	15	48 ^x - ?	6	15	4 ^x - ?
3	18	7 - ?	6	18	5 ^x - 6 ^x
3	21	14 - ?	6	21	23 ^x - ?
3	24	4 ^x - 12 ^x	6	30	14 ^x - 33 ^x
3	27	18 ^x - ?	6	33	50 ^x - 51 ^x
			6	36	40 ^x - ?

Concession	Lot	Minimum and Maximum Thickness of Drift (feet)	Concession	Lot	Minimum and Maximum Thickness of Drift (feet)
7	1	2 ^x - 3 ^x	9	3	7 ^x - 38 ^x
7	4	24 ^x - 27 ^x	9	6	23 - ?
7	7	9 ^x - 26 ^x	9	9	3 ^x - 30 ^x
7	10	3 ^x - 25 ^x	9	12	9 ^x - 14 ^x
7	13	12 ^x - 22 ^x	9	15	3 ^x - ?
7	16	20 ^x - 22 ^x	9	18	56 - ?
7	19	8 ^x - ?	9	21	4 ^x - ?
7	22	41 - ?	9	24	9 ^x - 35 ^x
7	25	? - 26 ^x	9	27	7 ^x - ?
7	31	34 - ?	9	30	9 ^x - ?
7	34	23 - ?	9	36	28 - ?
8	2	17 - ?	10	16	17 - ?
8	5	30 - ?	10	19	14 - ?
8	8	117 - ?	10	34	24 - ?
8	11	? - 40 ^x			
8	14	? - 24 ^x			
8	17	8 ^x - 27 ^x			
8	20	22 - ?			
8	29	115 - ?			
8	35	24 - ?			

^x to bedrock.

Water Supply

Except for a few localities, Edwardsburgh township appears to be fairly well supplied with ground water for both domestic and stock purposes. Exclusive of the communities, about 68.9 per cent of the wells throughout the township are of the dug type, and 31.1 per cent are drilled, chiefly into bedrock. Approximately 74.5 per cent are obtaining their water from depths of 40 feet or less. A survey of the well records shows that about 86.9 per cent of the wells have a permanent water supply sufficient for the present demands made upon them; the remainder constitute dry holes and wells that go dry intermittently, especially during periods of extended drought. In describing the principal beds that yield water to the wells, the statements of owners and drillers as to the character of the aquifer were necessarily accepted.

Clay till in the township is not a good source of water. Commonly, it constitutes a poor reservoir for ground-water storage as it takes up water slowly and holds relatively little. Furthermore, the slow circulation generally results in the quality of ground water obtained being poor. It is reported that shallow wells, dug 18 to 20 feet in clay till, are seldom satisfactory, especially when called upon to water 50 to 65 head of stock. The reason is the low permeability of the clay till that causes it to yield water slowly to the well. Consequently, a well deriving its ground water from it can be easily pumped dry and takes an exceedingly long time to refill. To overcome this difficulty, the owner should dig his well as deep as possible to form a reservoir large enough to provide sufficient water during times when large amounts are being drawn from the well. For instance, most wells dug an average of 34 feet in clay till are reported to provide a sufficient supply of ground water for 10 head of stock. The depth of the wells depends largely upon their topographic location. On higher ground, such as on or near the crest of a drumlin where many farm buildings are located, the wells should generally be deeper than those located on the lower, surrounding ground moraine.

In lots 26 and 27, con. VII, wells dug to depths of 35 to 52 feet in clay till are reported to be yielding excellent supplies of ground water.

A number of shallow wells dug in clay till reportedly encountered sand that for a time yielded water in sufficient quantities to satisfy the needs of the owner. However, after a period of time had elapsed, many of these wells assumed the properties of a well deriving its entire ground water supply from clay till, often going dry during the late summer or extended periods of drought, and yielding only limited supplies during normal times. It is thought that the sand encountered is in small isolated lenses of pockets in the till and that these sand beds, not being extensive, are drawing their limited supply of ground water from the confining till. Consequently, the quantity of water yielded by the sand would be no greater than if it were coming directly from the till into the well.

Ground water under hydrostatic pressure is seldom yielded directly by clay till. In most instances, the wells are non-artesian and are deriving their water from the zone of saturation below the water-table. Wells in areas where reworked clay till occurs on the surface are more satisfactory than in those areas of undisturbed clay till. This is due to the greater specific yield of the reworked material, which has had a large quantity of its finer particles washed from it.

Sufficient supplies of ground water, some of which is under pressure, is often, but not always, obtained at the contact of clay till and bedrock.

Although many of the kame deposits in the township are reported to yield an unsatisfactory supply of ground water, the material appears to be sufficiently permeable to yield its water fast enough to satisfy a normal pumping well. The water-table in the kame areas is relatively low and, consequently, the average depth of dug wells is greater than in other parts of the township. In the extreme northeast corner of the township, where kame sand directly overlies bedrock, most shallow wells, averaging 18 feet in depth and dug to bedrock, obtain a satisfactory supply of water from the zone directly above bedrock.

A large number of intermittent wells are reported to occur in the kame area in the southwest parts of the township. The kame material here is underlain principally by clay till. Because of the loose character and excessive permeability of the kame material, it is difficult for the average farmer to dig a well far enough below the water-table into the zone of saturation to obtain a permanent supply of water. It is considered best to dig wells in this type of material during the autumn or during periods when precipitation is low and the water-table has dropped to its lowest point. Deepening a dug, non-artesian well that is intermittent, in the hope of obtaining a permanent supply of ground water, is also best accomplished while the water-table is at its lowest point. Drilled wells employing well screens appear to be the most satisfactory means of obtaining a sufficient supply of ground water from these deposits.

Outwash sand and gravel does not appear to be an important source of water in the township. One well in lot 6, con. IV, was reported to have encountered 6 feet of gravel overlying bedrock and buried beneath 60 feet of marine clay. The water in this well is under considerable hydrostatic pressure and overflows for approximately 8 months of each year. It is possible that more of the water derived by wells drilled to bedrock in the township may be from a similar source, although such information is not recorded in the well data supplied by the owners.

Although marine clay does not appear on the surface to any great extent, it underlies a large part of the areas mantled with Champlain sand, and, accordingly, assumes a greater importance toward the ground-water conditions in the township than is at first apparent. The problems encountered in attempting to obtain satisfactory supplies of ground water from marine clay are comparable with those in clay till areas. Marine clay is too dense to yield its water content readily and wells dug in this material necessarily have to go a considerable distance below the water-table in order to provide a reservoir large enough to yield a satisfactory supply of water. Most wells dug in marine clay that are reported to be unsatisfactory, are so, not because of the lowering of the water-table, but because of the poor permeability of the material. For this reason a well

might be dug in clay a considerable distance below the water-table before there would be any evidence of free water. It is suggested that the only method to determine accurately the location of the water-table in clay is by making laboratory tests to determine if the material is saturated. A well dug in clay would necessarily have to remain in disuse for a considerable length of time before the elevation of the surface of the free water would approach that of the water-table.

Although it is a more laborious task to dig a well in heavy, marine clay than in sand or gravel, the slow entrance of the water makes it easier to penetrate the zone of saturation below the water-table and thus create a larger reservoir. In some wells, marine clay was found to be sufficiently firm and compact that lining the well with rock or wooden cribbing was not necessary. It is doubtful, however, if wells such as these would be as satisfactory as those that have been properly lined.

A number of shallow, intermittent wells, dug in marine clay, occur in the vicinity of Wexford, near Windmill Point and again near the junctions of Nos. 2 and 16 highways, both located in the extreme southwest corner of the township. These wells should be deepened to provide a greater reservoir. It was reported that shallow wells dug in marine clay will not provide sufficient ground water for 65 head of stock. In lot 29, con. I, where a thin layer of marine sand overlies the clay, a well drilled 83 feet into the clay was reported to be unsatisfactory whereas at the same time two adjacent, shallow, dug wells were reported to yield fair quantities of water. It is considered that the source of most of the water in these latter dug wells is the overlying marine sand, and that the casing of the nearby drilled well blocks off this water, allowing only a limited supply from the clay to enter through the relatively narrow opening in the bottom. In concession V, in the area surrounding Pittson, the Champlain sand deposits overlying the clay are thin, ranging from 2 to 3 feet in thickness. Dug wells in this locality, which range from 18 to 30 feet in depth, are reported to be obtaining their water directly from the clay.

The areas of marine sand yield fair to good supplies of ground water. Marine clay is the predominant material underlying the sand whereas smaller areas are underlain by clay till and bedrock. Precipitation falling upon sandy areas rapidly sinks in and percolates downward until it reaches the more impervious clay or clay till. These materials slow the downward movement of the water to such an extent that the sand above becomes saturated with water, frequently forming a perched water-table. Many wells dug down through the sand to the more impervious material are reported to have encountered "springs" in the bottom of the well. This is merely ground water seeping rapidly into the well from the saturated sand. It is difficult to determine if the water in wells dug through sand into the underlying clay is perched or not because the great permeability of the sand permits surface water to pass through it and fill the well rapidly to the level of the water in the perched water-table.

Shallow wells, 10 to 15 feet in depth, dug in areas where the marine sand deposits are exceptionally thick, encounter similar problems to those in kame areas. Few wells of this type are satisfactory, especially if located on a hill or ridge, where the greatest drop in the water-table occurs during a period of little precipitation. The most satisfactory wells in marine sand are those that are located in the flat sand areas between the higher areas of kame sand and glacial till. The water-table in these localities does not appear to fluctuate much and most wells can usually be depended upon to remain permanent the year round.

The few alluvial deposits in the township are not an important source of ground water. At Ventnor, however, 2 wells are believed to be deriving their water from alluvium and the supply is reported to be satisfactory for domestic uses.

Altogether, some 308 wells in the township have been drilled into bedrock, and all are reported to be deriving at least part of their ground water from that source. The depths of the wells range from 6 to 218 feet, with an average of 53 feet. All the wells are reported to be deriving their water from the March and Oxford formations with the exception of one. This well, a flowing artesian 160 feet deep, is located in lot 6,

con. IV, and is reported to be deriving its water from shale, presumably of the Rockcliffe formation. The water from this well has a "mineral" taste and an oily scum forms on its surface. It is not considered satisfactory for domestic use. Another well in lot 25, con. VII, is 218 feet deep and is reported to have passed through the Oxford and to have encountered either the March formation or the Precambrian. The water rose to approximately 2 feet from surface and is reported to be satisfactory for all domestic and farm uses. A well, 120 feet in depth, drilled at the Colonial Inn on No. 2 highway 2 miles east of Prescott is reported to have encountered granite underlying the limestone. The water in this well is under considerable pressure and rises to within 20 feet of the surface.

It is difficult to determine if the ground water in wells drilled to bedrock is under pressure when the elevation of the surface of the water are comparable to those in adjacent, shallow, dug wells. It is thought that most water encountered in bedrock is under pressure and, accordingly, rises some distance in the well, but in some wells this water is being supplemented by ground water from the zone of saturation lying above the artesian aquifer in the bedrock. This water, which may or may not be contaminated, enters at some point immediately below the casing and causes the surface of the water in the well to rise to the elevation of the water-table in that locality.

Not all wells that are drilled into bedrock provide sufficient quantities of ground water. In the area about Hyndman, in the northeast corner of the township, a number of wells drilled into the Oxford formation, one of which penetrated 100 feet of rock, were reported to yield insufficient quantities of water. The cheese factory in the same area, which has a 60-foot drilled well, reported an excellent supply. This suggests that aquifers that will provide sufficient quantities of water are present in the bedrock, but that there is an element of chance that such an aquifer will be encountered during drilling operations. Water may be obtained at almost any depth in bedrock down to the Precambrian. One well, in lot 25, con. VII, obtained water that rose to within 2 feet of surface after penetrating 192 feet of rock.

Flowing-artesian wells, obtaining their water from bedrock, are not common in Edwardsburgh township. The following is a list of such wells for which information has been obtained.

Lot	Concession	Well Depth (feet)	Bedrock Depth (feet)	Formation
1	III	85	70	Oxford
6	IV	160	22	Rockcliffe
7	V	100	89	Oxford
7	VI	64	?	Oxford
31	VI	?	?	Oxford
20	VII	52	12	Oxford

Information obtained from numerous wells drilled to bedrock indicates that the surface of bedrock underlying the township consists of a series of long, narrow, parallel ridges trending in a general southwest direction across the township and separated by wide, deep valleys filled with glacial drift. The relief of the bedrock surface is approximately 195 feet, ranging from 375 feet above sea-level in the vicinity of Groveton to a minimum of 100 feet or less as indicated by a 117-foot drilled well in lot 8, con. VIII.

All the flowing artesian wells and a number of excellent non-flowing artesian wells appear to be located upon the sides or flanks of the buried valleys. It is considered that not all the ground water obtained by these wells is derived from bedrock. Surface water percolating slowly down through the unconsolidated material and encountering bedrock would tend to accumulate in the valleys and form a source of ground water for any well put down in that area.

Although no accurate information has been obtained, it is thought that the relief of the surface of the Precambrian rocks beneath the sedimentary formations underlying the township is considerable, with numerous, rounded ridges of crystalline rocks interspersed with

valleys, in many instances partly filled with sandstone of the Nepean formation. The quantity of ground water that could be obtained from the larger of these sandstone beds should be considerable. Unfortunately, at present, drilling from surface appears to be the only means of locating them.

The entire surface of Edwardsburgh township acts as the intake area for the ground water yielded by both the overburden and the underlying bedrock. Some of the ground water derived from the bedrock formations may have originated southwest of the township in the areas north of Brockville, where the Precambrian rocks, which elsewhere underlie the Palaeozoic formations, appear on the surface. This is especially true in the south part of the township. The slope of the surface of the Precambrian rocks is in a general northeast direction, which is reflected by the similar low dip of the overlying sedimentary strata. There is no doubt but that a large part of the water yielded by several flowing-artesian wells in Augusta township, adjacent on the southwest, has its origin in this area.

Although numerous seepages occur around the edges of swamps and along the bases of the larger hills, no springs yielding large amounts of water were reported in the township. The seepages were considered to be indications of the outcropping of the water-table, which, in some localities, is probably perched.

Community Supplies

Ground-water conditions within the communities of Spencerville and Ventnor in the north part of the township, were investigated. Maps showing the location of all the wells within the communities for which information has been obtained accompany this report. Topographic contours, together with the contours of the bedrock surface in the case of Spencerville, and water-table contours in the case of Ventnor, are also indicated on these maps. Although these latter types of contours are somewhat generalized, they are believed to be sufficiently accurate for the purpose for which they are being used. Compilation sheets containing pertinent data concerning the individual wells in each community are attached at the back of this report.

Community of Spencerville. The water supply of the community of Spencerville is derived entirely from privately owned wells. Information has been compiled on 53 wells in the community; all of which, with one exception, are drilled and obtain at least part of their water from the underlying Oxford formation. The one exception is located at Willard's Lunch where the well was dug 7 feet to bedrock and then blasted 6 feet into the rock. Because most wells are tightly sealed at the surface, it was not possible to obtain sufficient information to produce a contour map of the water-table. However, a map depicting the contours of bedrock underlying the community has been produced. This map is based chiefly upon information received from the well owners.

The depths of drilled wells in Spencerville vary from 17 to 92 feet, with an average of 42 feet. The average depth to bedrock is about 5 feet, ranging from 0 to 15 feet from surface. The overburden consists of marine sand overlying clay till and/or bedrock. Bedrock outcrops in the bottom of South Nation River where it flows through the community as well as in scattered localities within the community itself.

The underlying dolomitic limestone appears to be a good source of water. The supply of the few wells that were reported as unsatisfactory could probably be increased by proper cleaning. The water appears to follow open fissures in the joints and bedding planes of bedrock. One well, which is approximately 400 feet from South Nation River and whose bottom is 9.5 feet below the river, is reported on good authority to be deriving organic material from these aquifers. This would suggest that there are large and continuous openings in the bedrock through which water will pass with relative ease. From this, it is believed that the allowing of numerous cesspools to drain directly into bedrock in the immediate vicinity of pumping wells is likely to cause pollution of the well waters and endanger the health of the well users. Some communal system of carrying away waste material should be considered. On examination of the accompanying contour map of the bedrock surface, the area immediately to the east of the community would appear to be the most satisfactory locality for waste disposal if a public sewage system were to be constructed.

Community of Ventnor This community is solely dependent upon privately owned wells for its domestic water supply. Altogether, there are 22 wells in the community, of which 7 are dug and are deriving their water from clay till or from alluvium along the flood plain of Nation River. The remaining 15 wells are drilled and are reported to be obtaining their water from the underlying Oxford formation. The average depth of the drilled wells is 42 feet and that of the dug wells is about 15 feet. Clay till is the predominant material overlying bedrock, which does not outcrop in the community itself but does in the bottom of South Nation River.

As the water levels in most wells are higher than the surface of South Nation River, it is doubtful if there is any contamination of the wells by sub-surface movement of water from the river through influent seepage. However, during a dry season when the water-table is at its lowest point, the water in the two wells located in the flood plain of the South Nation might receive river water. At the time they were measured, the elevation of their water surface was 2 feet above that of the river. One drilled well (J. Perry), in which the elevation of the water surface is about 2 feet above that of the river, is reported to fluctuate with the river. This does not necessarily mean that the water in the well is being contaminated by river water, but that the river is being fed by exfluent seepage from the water-table. Accordingly, when the water-table drops both the water in the well and in the river will drop at the same time. It would also indicate that there are openings in bedrock sufficiently large to permit fairly rapid movement of ground water.

On the map of Ventnor, which accompanies this report, both surface and water-table contours are indicated. To determine the depth to water in any one place, it is necessary only to subtract the elevation of the nearest water-table contour from that of the nearest surface contour.

Analyses of Water Samples

Twelve samples of well waters from Edwardsburgh township were analysed for their mineral content in the laboratory of the Mines Branch, Department of Mines and Technical Surveys, Ottawa. The samples were taken from wells varying in depth from 13 to 217 feet. The aquifers were assumed to be either in drift or in the underlying Oxford formation.

Except for wells Nos. 3 and 12, where the nitrate content appears to be abnormally high, the water from most of the wells listed in the table of analyses appears to be suitable for domestic and farm needs. It is suggested that bacteriological tests be made of the water from these two wells if they continue to be used for domestic purposes. Most contamination of well waters results from surface water seeping into the well either at the surface or at the bottom of the casing or cribbing. This is especially true for wells dug in marine clay. It is thought wells such as these whose waters have a strong odour of hydrogen sulphide and a "mineral" taste should be bacteriologically examined before being used.

Except for the chloride and sulphate content, there is a distinct similarity in the chemical analyses of the waters of the three flowing-artesian wells that were sampled. These wells were all reported to derive their ground-water supply from the Oxford formation. The water from the two flowing-artesian wells located in lot 1, con. III, and lot 6, con. IV, contain relatively large amounts of chloride whereas that from a flowing well in lot 7, con. VI, contains a large amount of sulphate chiefly as the salt of calcium or magnesium. From the analyses, it appears that the sulphate, principally in the form of CaSO_4 , is the most common mineral salt contained in the ground water derived from the Oxford formation throughout Edwardsburgh township.

Amounts of Dissolved Mineral Matter in Well Waters
Collected in Edwardsburgh Township
(Parts per million)

Constituent	Well waters from glacial drift and bedrock (12 samples)		
	Maximum	Average	Minimum
Residue on evaporation(105°C)	752	407	244
Calcium	110.9	54.3	38.3
Magnesium	45.0	28.1	21.0
Sodium	77.0	28.3	1.8
Potassium	26.0	7.4	1.4
Sulphate	148.2	56.3	20.6
Chloride	98.6	28.8	0.7
Nitrate	48.7	6.3	0
Bicarbonate	333.1	284.4	225.2
Carbonate	7.2	0.6	0
Silica (col.)	18.0	10.4	6.0
Total hardness	394.4	281.6	199.4

In answer to the requests of a number of well owners, the following method is recommended when it is desired to sterilize a well¹.

¹

Well Drilling, Technical Manual, TM 5-295, United States Government Printing Office, Washington, 1943.

Mix one heaping tablespoonful of chlorinated lime with a little water to make a thin paste, being sure to break up all lumps. Then stir this paste into 1 quart of water. Allow the mixture to stand a short time. Then pour off the clear liquid. The chlorine strength of the solution is about 1 per cent, and 1 quart of the liquid is enough to sterilize 800 imperial gallons of water.

Estimate the volume of water in gallons standing in the well and for each 800 imperial gallons pour 1 quart of the sterilizing solution into the well. No harm is done if too much solution is used, and it is better to use too much than too little. Agitate the water thoroughly, and let it stand for several hours, preferably over night. Then flush the well thoroughly to remove all the sterilizing agent. The sides of the well above the surface of the water can be sterilized by returning the water to the well during the first part of the flushing. Just before completion of the flushing a sample of the water may be taken if required.

To determine the amount of chlorinated lime solution that should be added to the well waters, it is necessary to know the diameter of the well and the depth of water in the well. With this knowledge, together with the information given in the table below, the volume of water present in the well can be easily calculated and, accordingly, the correct volume of lime solution added.

Diameter of well (feet)	Number of imperial gallons per foot depth
2.0	19.6
2.5	30.6
3.0	44.1
3.5	59.9
4.0	78.3
4.5	99.1
5.0	122.3

Conclusions

This investigation warrants the following conclusions:

1. Ground-water resources in Edwardsburgh township are in good supply and are adequate for domestic, stock, and community purposes.

2. Because of its low permeability, few shallow wells dug in clay till areas are satisfactory when called upon to water large numbers of stock.
3. Wells in the same areas usually yield good supplies of ground water. However, during times of drought, the water-table will drop below the bottom of the well and it will become dry. Deepening of the well during the period when the water-table is at its lowest point is suggested.
4. It is possible that a number of wells drilled into bedrock actually obtain their water from outwash sand and gravel lying directly above bedrock. There is only one authoritative confirmation of this in the township.
5. A large amount of the ground water reported to be yielded by marine clay in the township is actually coming from sand overlying the clay.
6. Except for a few wells that are improperly cased, the quality of ground water derived from glacial drift is quite suitable for domestic and farm use.
7. Bedrock appears to be a satisfactory source of ground water. In most cases the water is hard and clear with an insufficient content of total dissolved solids to render it unsatisfactory.
8. Most ground water encountered in the bedrock is under some hydrostatic pressure. However, in most cases this pressure is not sufficient to force the waters any great distance toward surface. The water in many such wells is augmented by water from the zone of saturation seeping into the well below the casing.
9. Because of the proximity of a number of cesspools to wells in the community of Spencerville there is great danger of enough pollution to endanger the health of many of the inhabitants.

10. The water from any shallow, dug well that emits a strong odour of hydrogen sulphide should be bacteriologically analysed.

Edwardsburgh Township

Summary of Wells and Springs used as a Source of Water Supply (exclusive of communities)

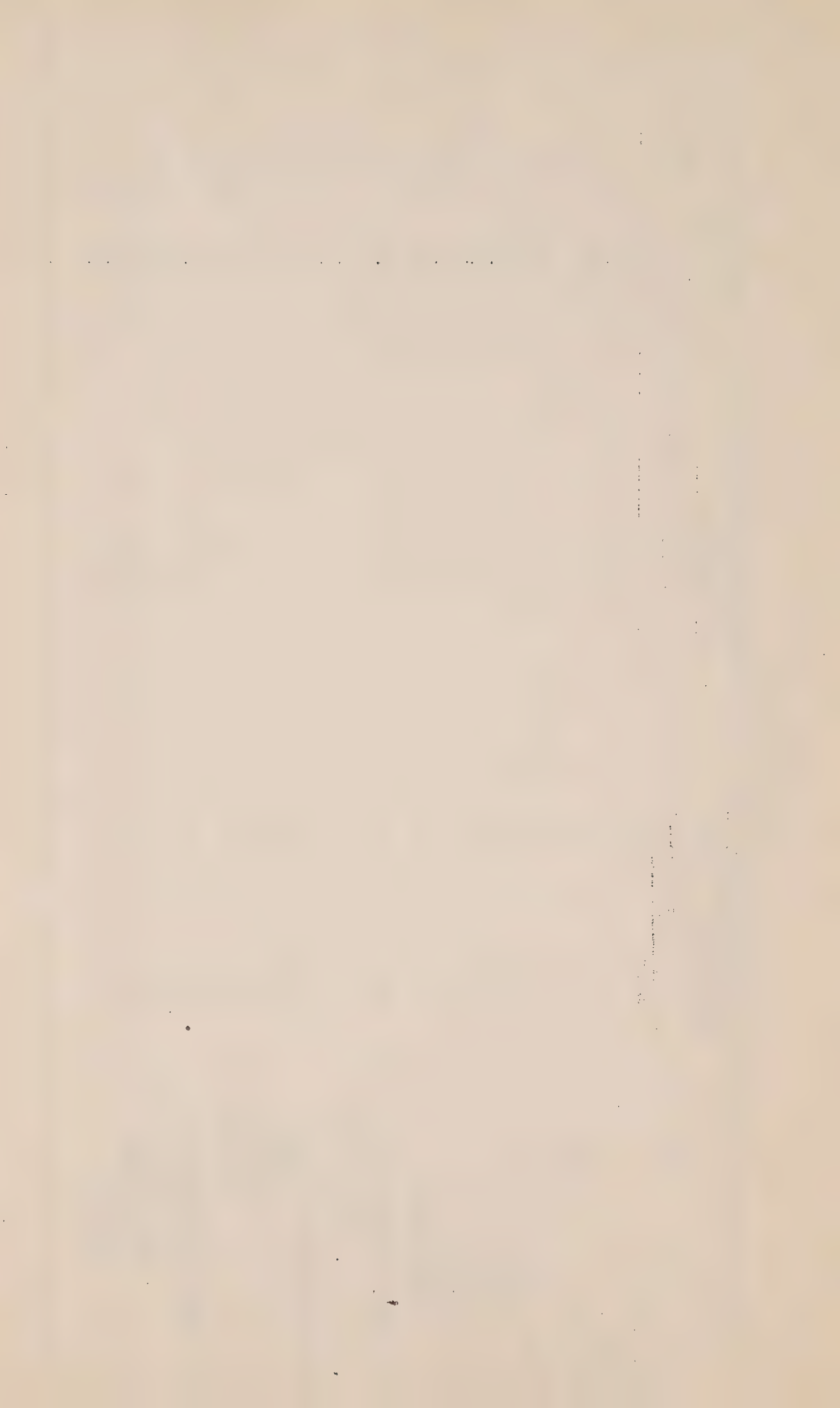
Wells and springs	CONCESSIONS										Total No in township	Per cent of total
	1	2	3	4	5	6	7	8	9	10		
Total number	193	82	102	82	117	133	109	79	77	17	991	68.90
Dug	134	65	75	59	94	89	70	43	40	14	683	
Bored	0	0	0	0	0	0	0	0	0	0	0	
Drilled	59	17	27	23	23	44	39	36	37	3	308	31.10
Springs	0	0	0	0	0	0	0	0	0	0	0	
Wells 0-20 feet deep	73	20	57	45	62	48	37	22	37	11	442	45.10
21-40	71	15	21	19	37	48	38	29	11	3	292	29.45
41-60	22	8	9	9	5	10	14	6	7	0	90	9.15
61-80	12	6	3	3	4	14	14	7	7	1	64	6.45
81-100	8	2	8	4	7	6	3	5	7	1	51	5.20
over 100	4	0	1	2	1	3	3	5	1	1	21	2.15
depth unknown	3	1	3		1	4		5	7	1	25	2.50
Wells that yield hard water	192	79	98	76	113	132	107	77	75	17	966	97.90
soft water	0	0	3	6	4	1	2	2	2	0	0	2.10
salty water	0	0	0	0	0	0	0	0	0	0	0	
Wells with aquifer in clay	31	1	8	0	32	8	3	5	9	0	97	9.75
in sand	59	45	43	42	46	46	26	13	21	15	363	36.50
in gravel	28	1	14	8	15	1	13	3	1	0	84	8.50
in glacial till	16	17	0	0	0	32	27	21	10	0	123	12.40
in bedrock	45	14	26	20	18	40	35	33	35	2	268	27.10
unknown	14	4	11	5	6	6	5	4	1	0	56	5.75
Well types: Flowing artesian	0	0	1	2	1	3	1	0	0		8	0.80
Non-flowing artesian	36	10	20	15	8	22	12	14	18	1	156	15.75
Non-artesian	112	53	61	53	87	96	86	55	47	13	663	66.90
Intermittent	34	15	17	11	15	9	10	8	9	2	130	13.10
Dry holes	0	0	2	1	1	1	0	0	2	0	8	0.80
Not used	9	9	7	10	21	19	21	14	16	1	127	12.80



Edwardsburgh Township

Summary of Wells and Springs used as a Source of Water Supply in Communities

	Communities		Total number in communities	Per cent of total
	Spencerville	Ventnor		
Total number	53	22	75	100.00
Dug	1	7	8	10.70
Bored	0	0	0	—
Drilled	52	14	66	88.00
Springs	0	0	0	—
Wells				
0-20 feet deep	2	5	7	9.35
21-40	17	5	22	29.15
41-60	7	6	13	17.35
61-80	8	0	8	10.70
81-100	5	0	5	6.65
over 100	0	0	0	—
depth unknown	15	6	21	28.00
Wells that yield hard water	52	20	72	96.00
soft water	1	0	1	1.30
salty water	0	0	0	—
Wells with aquifer in clay	0	0	0	—
in sand	0	0	0	—
in gravel	0	0	0	—
in till	0	5	5	6.65
in bedrock	53	14	67	89.40
Well types:				
Flowing artesian	0	0	0	—
Non-flowing artesian	20	10	30	40.00
Non-artesian	30	5	35	46.60
Intermittent	1	2	3	4.00
Dry holes	0	0	0	—
Not used	5	2	7	9.35



Analyses of Well Waters from Edwardsburgh Township, Grenville County, Ontario

Sample Number	Owner	Lot	Concession	Depth of Well (Feet)	Aquifer	Total dissolved solids (parts per million)	Silica (SiO ₂)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Constituents as Analysed (parts per million)					Hardness as CaCO ₃ (pts. per million)			
											Alkalis (as Na)	Sulphate (SO ₄)	Chloride (Cl)	Nitrate (NO ₃)	Bicarbonate (HCO ₃)	Alkalinity (as CaCO ₃)	Ca hardness (as CaCO ₃)	Mg hardness (as CaCO ₃)	Total hardness (as CaCO ₃)
1	R. Armstrong	1	III	85	0	306	13.8		48.5	38.4	42.2	34.6	46.5	0	272.1		124.5	140.3	264.8
2	G. A. Lane	9	IV	160	0	524	7.8		48.6	28.4	73.9	31.7	98.9	0.7	305.7		121.0	116.9	237.9
3	G. Montgomery	8	V	37	c/o	752	10.2		110.9	28.6	92.8	148.2	74.1	48.7	317.7		276.7	117.7	394.4
4	G. Montgomery	8	V	100	0	362	13.2		41.0	28.2	52.4	20.6	54.5	0	263.5		102.3	116.0	218.3
5	H. Richardson	9	V	13	s/c	244	15.2		41.0	23.9	11.70	22.6	5.8	0.7	229.4		102.3	97.1	199.4
6	H. Anderson	7	VI	64	0	454	12.2		62.3	45.0	27.0	84.8	19.3	0	314.8		155.4	185.2	340.6
7	J.S. Wallace	10	VI	15	s/c	288	6.0		51.9	28.6	3.7	29.6	2.2	2.3	278.2		129.5	117.7	247.2
8	L.W. Keeler	26	VI	27	0	496	6.4		90.7	37.8	11.3	86.4	10.6	Tr.	333.1		226.3	165.5	391.8
9	W.H. Connell	25	VII	217	0	280	9.6		56.7	28.2	5.8	21.8	0.7	0	270.2		141.5	116.0	256.5
10	J.L. Pelton	7	IX	60	0	284	18.0		38.3	21.0	8.1	38.7	9.2	0	225.2		145.5	86.4	231.9
11	C. Gilmer	10	IX	120	0	364	6.8		46.7	31.0	53.5	42.0	18.3	1.4	309.1		116.5	127.6	244.1
12	Somerville	29	IX	77	0	524	7.8		103.3	22.9	32.8	114.8	7.7	21.3	293.0		257.7	94.2	351.9

ABBREVIATIONS

The following is a list of abbreviations used in the included water well compilation sheets for the communities of Ventnor and Spencerville.

Type:

Drl. - drilled
D. - dug

Depth to Water Surface:

M. - measured

Aquifer:

Al. - alluvium
C.T. - clay till
Ox. - Oxford formation

Quality:

C. - clear
Cl. - cloudy
H. - hard
I. - irony
S. - soft

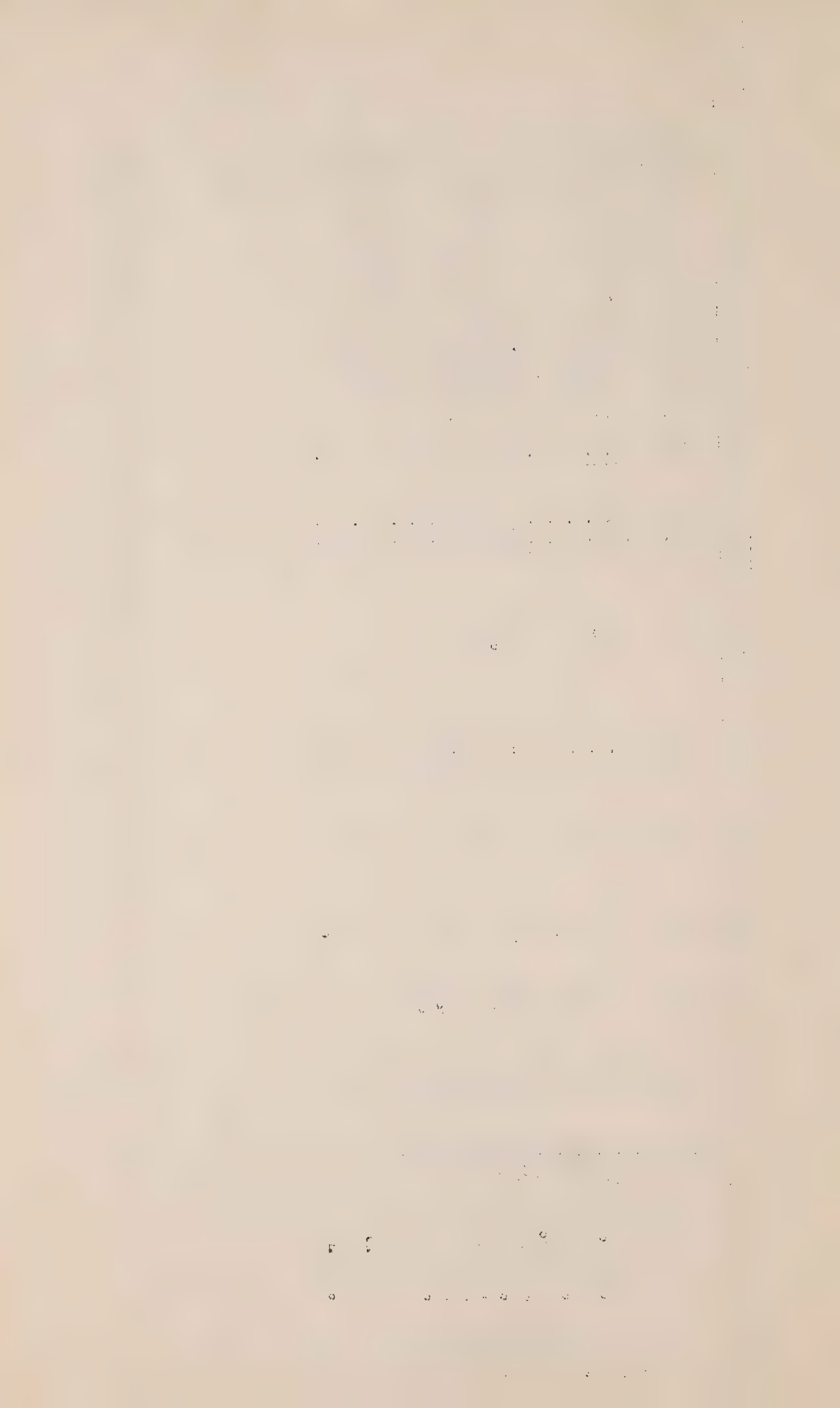
Use:

D. - domestic
N. - not used
S. - stock

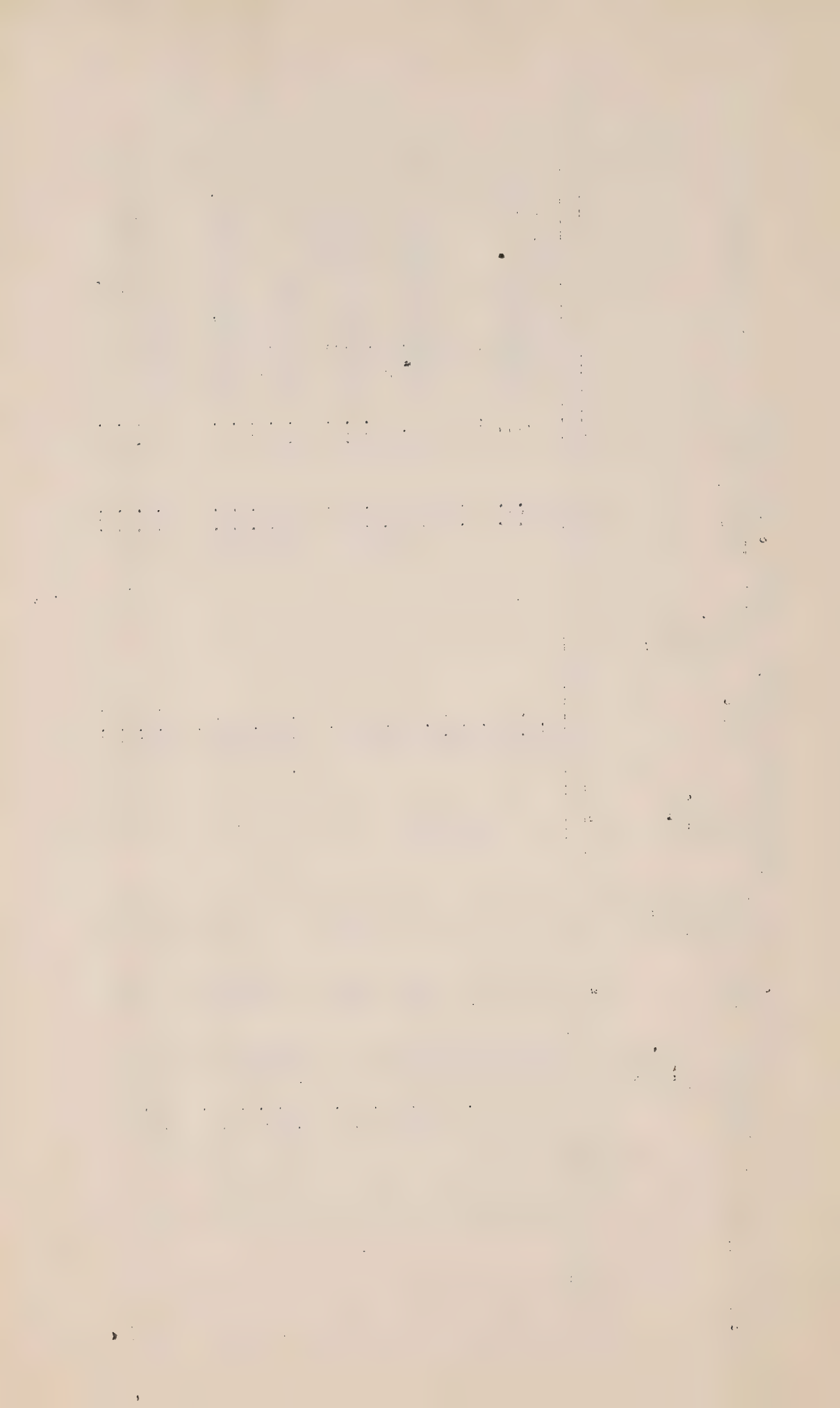
Community of Spencersville, Edwardsburgh Township, Grenville County, Ontario

1	2	3	4	5	6	7	8	9	10	11	12	13
1	60	26	Drl.	303	32	15	5	Ox.		H.C.	D.	Sufficient
2	6	26	Drl.	305	40		10	Ox.		H.C.	D.	Sufficient for 2 families
3	6	26	Drl.	300			7	Ox.		H.C.	N.	"
4	6	26	Drl.	290	36	8	1	Ox.		H.I.	D.	Sufficient.
5	6	27	Drl.	311	26	10	4	Ox.		H.C.	D.	"
6	6	27	Drl.	314	51	16	9	Ox.		S.C.	D.	Sufficient for 3 families
7	6	27	Drl.	316			9	Ox.		H.C.	N.	Sufficient
8	6	27	Drl.	320	90		0	Ox.		H.C.	D.	"
9	6	27	Drl.	316	56		1	Ox.		H.C.	D.	Sufficient for 2 families
10	6	27	Drl.	316	80		1	Ox.		H.C.	D.	"
11	6	26	Drl.	305			15	Ox.		H.C.	D.	"
12	6	26	Drl.	307	40	20	6	Ox.		H.C.	D.	Sufficient
13	6	26	Drl.	303	65	15	11	Ox.	14+	H.C.	D.	Sufficient for 5 families
14	6	27	Drl.	320	50	12	7	Ox.	10+	H.C.	D.	"
15	6	27	Drl.	317	65	8	10	Ox.		H.C.	D.	Sufficient
16	6	27	Drl.	310	80			Ox.		H.C.	D.	"
17	6	27	Drl.	316	45		4	Ox.	10+	H.C.	D.	Sufficient for 3 families
18	6	27	Drl.	319	30	15	3	Ox.		H.C.	D.	Goes dry in summer
19	6	27	Drl.	302	17	3M.	7	Ox.		H.C.	D.	Sufficient
20	6	26	Drl.	306	37	20	3	Ox.		H.C.	D.	"
21	6	27	Drl.	316	30		5	Ox.		H.C.	D.	"
22	6	27	Drl.	313				Ox.		H.C.	N.	Sufficient
23	6	27	Drl.	312			4	Ox.		H.C.	D.	"
24	6	27	Drl.	316	39		4	Ox.		H.C.	D.	Sufficient
25	6	26	Drl.	302	32	10M	10	Ox.		H.C.	D.	"
26	6	27	Drl.	319			1	Ox.		H.C.	D.	"
27	6	27	Drl.	315	35		3	Ox.	6+	H.C.	D.	Sufficient for 2 families; 48° F
28	6	26	Drl.	307	27	14M	1	Ox.		H.C.	D.	Sufficient
29	6	27	Drl.	319			1	Ox.		H.C.	D.	" ; at house
30	6	26	Drl.	301	45		3	Ox.		H.C.	S.	" ; at barn
31	6	26	Drl.	300	26			Ox.	26+	H.C.	D.	Sufficient
32	6	26	Drl.	299				Ox.		H.C.	D.	"
33	6	27	Drl.	317			1	Ox.		H.C.	D.	"
34	6	26	Drl.	303	90			Ox.		H.C.	D.	"
35	6	26	Drl.	301		5M	7	Ox.	26+	H.C.	N.	Vacant house
36	6	26	Drl.	302	60			Ox.		H.C.	D.	Sufficient for service station

1	2	3	4	5	6	7	8	9	10	11	12	13
37	6	27	Drl.	322	22	15	4	Ox.	7+	H.Cl.	D.S.	Sufficient for Hotel; excellent supply
38	6	26	Drl.	301	30	7	9	Ox.		H.C.	D.	
39	6	26	Drl.	302		4M	6	Ox.		H.C.	N.	
40	6	26	Drl.	302			3	Ox.		H.C.	D.	Sufficient; excellent supply
41	6	26	Drl.	304	85			Ox.	20+	H.C.	D.	Sufficient for 4 families
42	6	27	Drl.	310	44	13	1	Ox.		H.C.	D.	Sufficient
43	6	27	Drl.	305		6	6	Ox.		H.C.	D.	"
44	6	26	Drl.	303	60			Ox.		H.C.	D.	"
45	6	27	Drl.	317	85	25		Ox.		H.C.	D.	Sufficient
46	6	26	Drl.	301	21	8	4	Ox.	6+	H.C.	D.	Sufficient for 2 families
47	6	26	Drl.	304			4	Ox.	30+	H.C.	D.	Sufficient for 10 families
48	6	27	Drl.	315			4	Ox.		H.C.	D.	Sufficient for manse
49	6	27	Drl.	322	63+	25M		Ox.		H.C.	D	"
50	6	26	Drl.	306	66		2	Ox.		H.C.	D	"
51	6	27	Drl.	318	92		0	Ox.		H.C.	D.S.	Sufficient for race track
52	6	25	Drl.	313	28		2	Ox.		H.C.	D.	excellent supply
53	6	26	D.	300	13	6M	7	Ox.		H.C.	D.	Sufficient for school; excellent supply.



Well	Conc.	Lot	Type	Altitude in feet above sea- level	Depth (feet)	Depth to Water Surface (feet) (June 1950)	Depth to Bedrock (feet)	Aquifer	Yield gals. per hour (approx)	Quality	Use	Remarks
1	2	3	4	5	6	7	8	9	10	11	12	13
1	7	16	Drl.	282	55	20	6	Ox.		H.C.	D	Excellent supply at house
2	8	15	D.	288	8	6		C.T.		H.C.	D	Goes dry during summer
3	8	16	Drl.	286	35	8	4	Ox.		H.C.	D	Sufficient for 2 families
4	8	15		284				Ox.			N.	Vacant house
5	8	16	Drl.	292	60M	15M	14	Ox.		H.C.	N	
6	8	16	D.	290			20	C.T.			N	
7	8	16	Drl.	290	60	14	20	Ox.	5 +	H.C.	S	Sufficient; at barn
8	8	16	Drl.	292	60		20	Ox.		H.C.	D.S.	Excellent supply at store
9	8	16	Drl.	284	22M	11M	4	Ox.		H.C.	D.	Sufficient for 2 families
10	8	16	Drl.	288				Ox.		H.C.	D.	" " 2 "
11	7	15	D.	287	14M	8M		C.T.		H.C.	D.S.	Sufficient; at house
12	8	16	Drl.	290	29M	14M	7	Ox.		H.C.	D.	Sufficient for school and two families
13	7	15	D.	286	15M	7M		C.T.		H.C.	D.S.	Sufficient; at house
14	8	16	Drl.	280				Ox.		H.C.	D.	Low in summer; at house
15	7	15	Drl.	284			7	Ox.		H.C.	D.	" " " "
16	8	16	Drl.	286	45+	2M	2	Ox.		H.C.	D.	Sufficient for cheese factory
17	7	15	D.	288	26M	8M		C.T.		H.C.	D.	Sufficient; at house.
18	7	15	Drl.	288	41M	16M	26	Ox.		H.C.	S.	Not sufficient for 11 head; at barn
19	8	15	D.	278	14M	4M		Al.(?)		H.C.	D.	Sufficient; at house
20	7	16	Drl.	284	30	12	5	Ox.	4 +	H.C.	D.S.	Sufficient; at barn
21	8	16	Drl.	290		13M	13	Ox.		H.C.	D.	" " " "
22	8	15	D.	278	14M	4M		Al.(?)		H.C.	D.	Seldom used.



MAP 2 VENTNOR

LEGEND

Topographic contours . . . — 282 —

Water-table contours . . . - - - 276 - - -

Well, location and number x 9

(Ground-water data gathered June 1950)

Scale of Feet

200 0 200

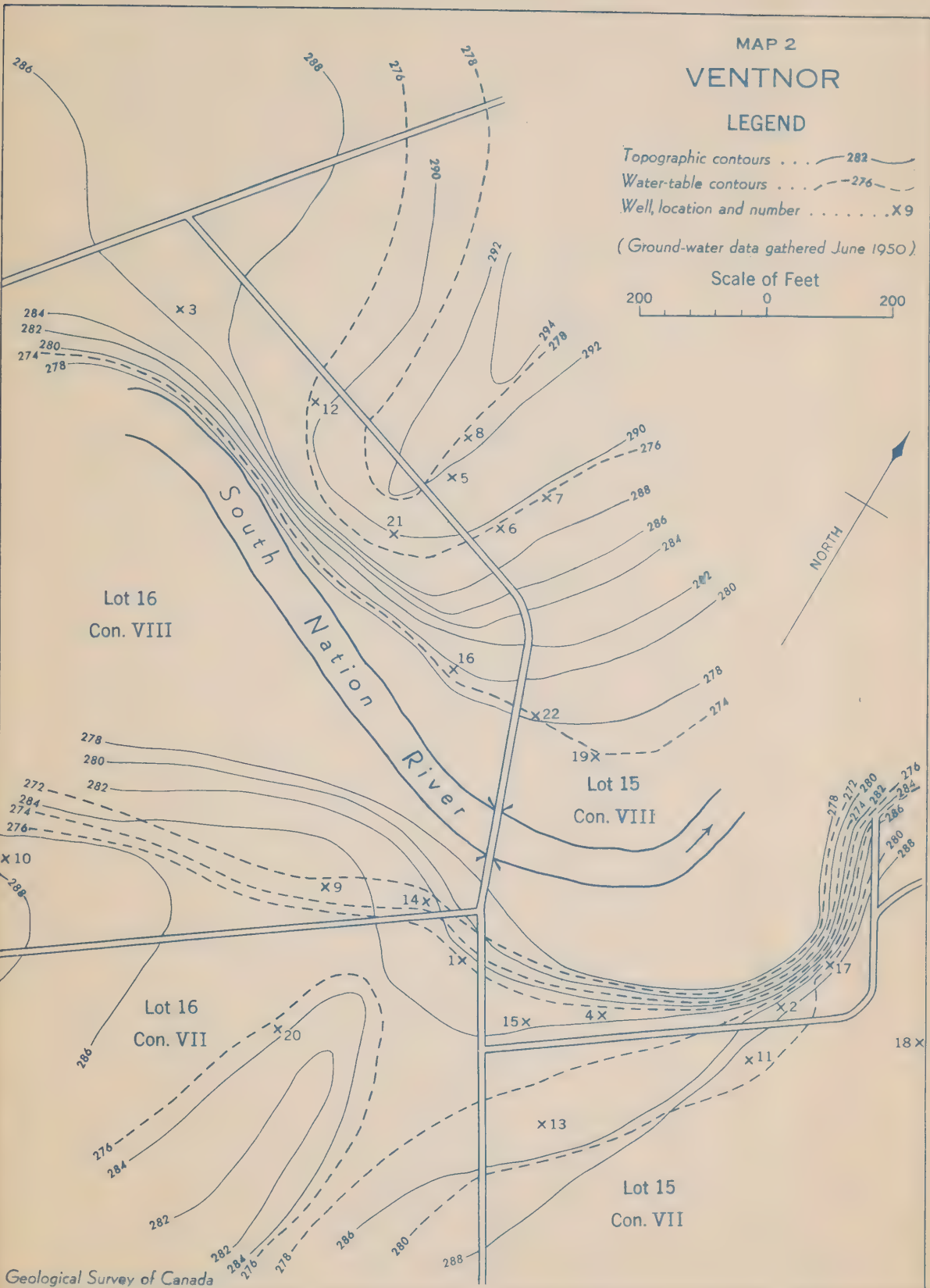
NORTH

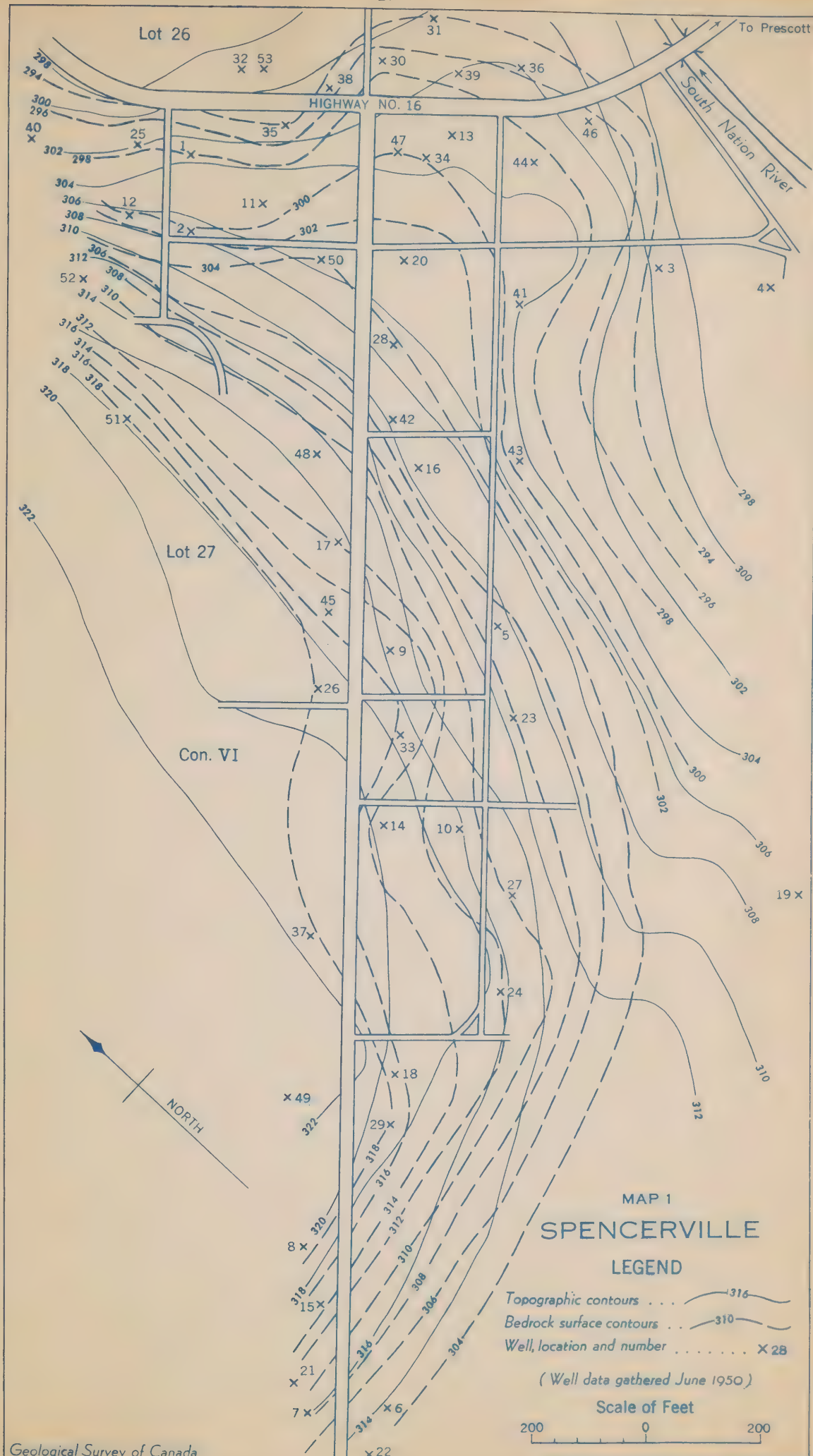
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Government
Publications

CANADA
DEPARTMENT OF MINES
AND
TECHNICAL SURVEYS

GEOLOGICAL SURVEY OF CANADA
WATER SUPPLY PAPER No. 317

11

GROUND-WATER RESOURCES
OF
TOWNSHIPS 35 to 38, RANGES 1 to 4,
WEST OF 5th MERIDIAN
ALBERTA
(Markerville Area)

By
A. Mac S. Stalker



DEPARTMENT OF GEOLOGICAL SCIENCES,
UNIVERSITY OF TORONTO

OTTAWA
1953

CANADA

NOTE:

Because of difficulties involved in reproduction, the tables of well records referred to are not included with this report. Information regarding individual wells may be obtained by writing to the Director, Geological Survey of Canada, Ottawa.

By
A. MacS. Stalker

OTTAWA
1951

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CANADA

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Illustrations

Preliminary map - townships 35 to 38, ranges 1 to 4,
west 5th meridian, Alberta:

Figure 1. Map showing surficial material;

2. Map showing topography and location and
types of wells.

INTRODUCTION

The survey of the ground-water resources of the Red Deer region, Alberta, was resumed during the field season of 1946, and much information on these resources was obtained by a compilation of records of water wells.

A division has been made in the well records, in so far as possible, between the glacial and bedrock water-bearing sands. The water records themselves were obtained mostly from the well owners, some of whom had acquired the land after the water supply had been found, and hence had no personal knowledge of the water-bearing beds that had been encountered in their wells. Also, the elevations of the wells were taken by aneroid barometer and are, consequently, only approximate. In spite of these defects, however, it is hoped that the publication of these water records may prove of value to the farmers, town authorities, and drillers in their efforts to obtain adequate water supplies.

Publication of Results

The essential information pertaining to ground-water conditions is being issued in reports that in Saskatchewan cover each municipality, and in Alberta cover each square block of sixteen townships beginning at the 4th meridian and lying between the correction lines. The secretary-treasurer of each municipality in Saskatchewan and Alberta will be supplied with the information covering that municipality. Copies of the reports will also be available for study at offices of the Provincial and Federal Departments. Further assistance in the interpretation of the reports may be obtained by applying to the Chief Geologist, Geological Survey, Ottawa. Technical terms used in the report are defined in the glossary.

How to Use the Report

Anyone desiring information concerning ground water in any particular locality will find the available data listed in the well records. These should be consulted to see if a supply of water is likely to be found in shallow wells sunk in the glacial drift, or whether a better supply may be obtained at greater depth in the underlying bedrock formations. The wells in glacial drift commonly show no regional level, as the sands or gravels in which the water occurs are irregularly distributed and of limited extent. As the surface of the ground is uneven, the best means of comparing water wells is by the elevations of their water-bearing beds. For any particular well this elevation is obtained by subtracting the figure for the depth of the well to the water-bearing bed from that for the surface elevation at the well. For convenience, both the elevation of the wells and the elevation of the water-bearing bed or beds in each well are given in the well-record tables. Where water is obtained from bedrock, the name of the formation in which the water-bearing sand occurs is also listed in these tables, and this information should be used in conjunction with that on bedrock formations, provided in the report, which describes these formations and gives their thickness and sequence. Where the level of the water-bearing sand is known, its depth at any point can easily be calculated by subtracting its elevation, as given in the well-records tables, from the elevation of the surface at that point.

With each report is a map consisting of two figures. Figure 1 shows the distribution and type of surface deposits and bedrock formation that occur in the area. Figure 2 shows the locations of all wells for which records are available, the class of well at each location, and the contour lines or lines of equal elevation. The elevation at any location can thus be roughly judged from the nearest contour line, and the records of the wells show at what levels water is apt to be encountered. The depth of the well can then be calculated, and some information on the character and quantity of water can be obtained from a study of the records of surrounding wells.

GLOSSARY OF TERMS USED

Alkaline. The term "alkaline" has been applied rather loosely to some ground waters that have a peculiar and disagreeable taste. In the Prairie Provinces, water that is commonly described as alkaline usually contains a large amount of sodium sulphate and magnesium sulphate, the principal constituents of Glauber's salt and Epsom salts respectively. Most of the so-called alkaline waters are more correctly termed sulphate waters, many of which may be used for stock without ill effect. Water that tastes strongly of common salt is described as salty.

Alluvium. Deposits of earth, clay, silt, sand, gravel, and other material on the flood-plains of modern streams and in lake beds.

Aquifer. A porous bed, lens, or pocket in unconsolidated deposits or in bedrock that carries water.

Buried pre-Glacial Stream Channel. A channel carved into bedrock by a stream before the advance of the continental ice-sheet, and subsequently either partly or wholly filled in by sands, gravels, and boulder clay deposited by the ice-sheet or later agencies.

Bedrock. Bedrock, as here used, refers to partly or wholly consolidated deposits of gravel, sand, silt, clay, and marl that are older than the glacial drift.

Coal Seam. The same as a coal bed. A deposit of carbonaceous material formed from the remains of plants by partial decomposition and burial.

Contour. A line on a map joining points that have the same elevation above sea-level.

Continental Ice-sheet. The great ice-sheet that covered most of the surface of Canada many thousands of years ago.

Escarpment. A cliff or a relatively steep slope separating level or gently sloping areas.

Flood-plain. A flat part in a river valley ordinarily above water but covered by water when the river is in flood.

Glacial Drift. The loose, unconsolidated surface deposits of sand, gravel, and clay, or a mixture of these, that

were deposited by the continental ice-sheet. Clay containing boulders forms part of the drift and is referred to as glacial till or boulder clay. The glacial drift occurs in several forms:

(1) Ground Moraine. A boulder clay or till plain (includes areas where the glacial drift is very thin and the surface uneven).

(2) Terminal Moraine or Moraine. A hilly tract of country formed by glacial drift that was laid down at the margin of the continental ice-sheet during pauses in its retreat. The surface is characterized by irregular hills and undrained basins.

(3) Glacial Outwash. Sand and gravel plains or deltas formed by streams that issued from the continental ice-sheet.

(4) Glacial Lake Deposits. Sand and clay plains formed in glacial lakes during the retreat of the ice-sheet.

Ground Water. Sub-surface water, or water that occurs below the surface of the land.

Hydrostatic Pressure. The pressure that causes water in a well to rise above the point at which it is first encountered.

Impervious or Impermeable. Beds, such as fine clays or shale, are considered to be impervious or impermeable when they do not permit of the perceptible passage or movement of ground water.

Pervious or Permeable. Beds are pervious when they permit of the perceptible passage or movement of ground water, as for example porous sands, gravel, and sandstone.

Pre-Glacial Land Surface. The surface of the land before it was covered by the continental ice-sheet.

Recent Deposits. Deposits that have been laid down by the agencies of water and wind since the disappearance of the continental ice-sheet.

Unconsolidated Deposits. The mantle or covering of alluvium and glacial drift consisting of loose sand, gravel, clay and boulders that overlies the bedrock.

Water-table. The upper limit of the part of the ground wholly saturated with water. This may be very near the surface or many feet below it.

Wells. Holes sunk into the earth so as to reach a supply of water. When no water is obtained they are referred to as dry holes. Wells in which water is encountered are of three classes.

(1) Wells in which the water is under sufficient pressure to flow above the surface of the ground.

(2) Wells in which the water is under pressure but does not rise to the surface.

(3) Wells in which the water does not rise above the water-table.

BEDROCK FORMATIONS OF EAST-CENTRAL ALBERTA

The formations that outcrop in east-central Alberta are of Tertiary and Upper Cretaceous age, and consist entirely of relatively soft shales and sandstones, with some bands of hard sandstone and layers of ironstone nodules. The succession, character, and estimated thickness of the formations are shown in the following table:

Age	Formation	Character	Thickness
Tertiary	Paskapoo	Light grey sandstone, in part carbonaceous; shale; small amounts of siliceous limestone and volcanic dust; coal seams.	Feet 800 \pm
	Edmonton	Grey to white, bentonitic sands and sandstones, with grey and greenish shales; coal seams prominent in some areas, as at Drumheller.	1,000 to 1,150
	Bearpaw	Dark shales, green sands with smooth, black chert pebbles; partly non-marine, with white bentonic sands, carbonaceous shales, or thin coal seams similar to those in Pale Beds; shales at certain horizons contain lobster-claw nodules and marine fossils; at other horizons selenite crystals are abundant.	300 to 600
Upper Cretaceous	Pale and Variegated Beds	Light grey sands with bentonite; soft, dark grey and light grey shales with selenite and ironstone; carbonaceous shales and coal seams; abundant selenite crystals in certain layers.	600 \pm
	Birch Lake (?)	Grey sand and sandstone in upper part; middle part of shales and sandy shales, thinly laminated; lower part with grey and yellow weathering sands; oyster bed commonly at base.	100 \pm
	Grizzly Bear	Mostly dark grey shale of marine origin, with a few minor sand horizons; selenite crystals and nodules up to 6 or 8 inches in diameter.	100 -
	Ribstone Creek	Grey sands and sandstones at the top and bottom with intermediate sands and shales; mostly non-marine, but middle shale in some areas is marine.	325 -

WATER ANALYSES

Introduction

The following discussion of water analyses is included to assist those who wish to know the effect of various mineral constituents in well water, which give the water in some wells certain peculiar qualities.

Discussion of Chemical Determinations

The dissolved mineral constituents vary with the material encountered by the water in its migration to the reservoir bed. The mineral salts present are referred to as the total dissolved solids, and they represent the residue when the water is completely evaporated. This is expressed quantitatively as "parts per million", which refers to the proportion by weight in 1,000,000 parts of water. A salt when dissolved in water separates into two chemical units called "radicals", and these are expressed as such in the chemical analyses. In the one group is included the metallic elements of calcium (Ca), magnesium (Mg), and sodium (Na), and in the other group are the sulphate (SO_4), chloride (Cl), and carbonate (CO_3) radicals.

Mineral Constituents Present

Calcium (Ca) in the water comes from mineral particles present in the surface deposits, the chief source being limestone, gypsum, and dolomite. Fossil shells provide a source of calcium, as does also the decomposition of igneous rocks. The common compounds of calcium are calcium carbonate (CaCO_3) and calcium sulphate (CaSO_4).

Magnesium (Mg) is a common constituent of many igneous rocks and, therefore, very prevalent in ground water. Dolomite, a carbonate of calcium and magnesium, is also a source of the mineral. The sulphate of magnesium (MgSO_4) combines with water to form "Epsom salts", and if present in large amounts imparts a bad taste and is detrimental to the health.

Sodium (Na) is derived from a number of important rock-forming minerals, so that sodium sulphate and carbonate are very common in ground waters. Sodium sulphate (Na_2SO_4) combines with water to form "Glauber's salts", which if present in amounts over 1,200 parts per million makes the water unfit for domestic use or for irrigation. Sodium carbonate (Na_2CO_3) or "black alkali" waters are mostly soft, the degree of softness depending upon the ratio of sodium carbonate to the calcium and magnesium salts. Waters containing sodium carbonate in excess of 200 parts per million are unsuitable for irrigation.

Chlorine (Cl) is, with a few exceptions, expressed as sodium chloride (NaCl), which is common table salt. When found in water in excess of 400 parts per million it renders the water unfit for domestic use.

Iron, when present in more than 0.1 parts per million, will settle out of the water as a red precipitate on exposure to the air. Water that contains not more than 0.5 parts per million

is considered the usual upper limit for potable water, but this amount is often exceeded. A water that contains considerable iron will stain porcelain, enamel ware, and clothing that is washed in it, but the iron can be almost completely removed by aeration and filtration of the water.

Hardness. Hardness is of two kinds, temporary and permanent. Temporary hardness is caused by calcium and magnesium bicarbonates, which are soluble in water but are precipitated as insoluble normal carbonates by boiling, as shown by the scale that forms in teakettles. Permanent hardness is caused by the presence of calcium and magnesium sulphates, and is not removed by boiling. Waters grade from very soft to very hard, and can be classified according to the following system¹.

¹ The "Examination of Waters and Water Supplies"; Thresh and Beale, Fourth Ed. 1933, p. 21.

A water under 50 degrees (that is, parts per million) of hardness may be said to be very soft.

A water with 50 to 100 degrees of hardness may be said to be moderately soft.

A water with 100 to 150 degrees of hardness may be said to be moderately hard.

A water with more than 200 and less than 300 degrees of hardness may be said to be hard.

A water with more than 300 degrees of hardness may be said to be very hard.

Hard waters are usually high in calcium carbonate. Almost all of the waters from the glacial drift are of this type, particularly those not associated with sand and gravel deposits that come close to the surface.

In soft water the calcium carbonate has been replaced by sodium carbonate, due to natural reagents present in the sands and clays. Bentonite and glauconite are two such reagents known to be present. Montmorillonite, one of the clay-forming minerals, has the same property of softening water, owing to the absorbed sodium that is available for chemical reaction.²

² Piper, A.M.: "Ground Water in Southern Pennsylvania", Penn. Geol. Surv., 4th series.

If surface water reaches the lower sands by percolating through the higher beds it may be highly charged with calcium salts before reaching the bedrock formations containing bentonite or glauconite. The completeness of the exchange of calcium carbonate for sodium carbonate will, therefore, depend upon the length of time that the water is in contact with the softening reagent, and also upon the amount of this material present. The rate of movement of underground water will, consequently, be a factor in determining the extent of the reaction.

TOWNSHIPS 35 TO 38, RANGES 1 TO 4,
WEST 5TH MERIDIAN, ALBERTA
(Markerville Area)

Introduction

The investigation of ground-water resources in Alberta was continued during the summer of 1950 by the writer, ably assisted by K. F. Pallett. The surficial material was also mapped, and the relation of both it and the underlying bedrock to the ground-water supply studied.

Physical Features

Red Deer River flows through the southern townships of the area and three rivers are tributary to it in this section of its course. The Little Red Deer enters from the south, Medicine River enters from the north, and Raven River joins it from the west.

As Red Deer River rises in the Rocky Mountains, it has a fair volume of water all year, but is particularly high when the snow melts in the mountains in June and July. It flows through the area in an old valley 100 feet deep, and has a gradient greater than 10 feet to a mile. It enters the area in a wide, braided channel, with large gravel deposits and a wide flood plain, and much of its water seeps through the gravel. In the east of the area the current is slower, the valley narrower, and the river has lost much of the heavy load derived from the mountains. Little Red Deer River has a gradient of 15 or 20 feet to a mile and maintains a fairly even volume of water all summer. Its valley is steep-walled, and increases rapidly in depth from a few feet to 110 feet near where it joins the Red Deer. The meandering Medicine River rises locally. It floods in spring, but practically disappears during the summer. This river differs markedly from the others, as it has only the low gradient of about $1\frac{1}{2}$ feet to a mile, and during most of the year is slow flowing. Its valley appears old, and the land slopes towards the river for many miles on either side. Raven River is a small, meandering stream

that occupies only a small part of a valley several miles wide and 100 or 200 feet deep. Its large valley and the considerable amounts of alluvium present indicate that a large river, perhaps the Clearwater, once flowed in this valley.

Among the other valleys of importance, one, floored with thick alluvium, is occupied by Dickson Creek. Another large one, occupied by Tindaston Creek in the lower reaches, extends north to Cygnet and Sylvan Lakes. Many other valleys not now used by streams are present, mainly in the southwest. Most of these, formed during the retreat of the last ice or in interglacial time, trend southeastward. Gravel is generally present near such valleys.

The topography of the area may be divided conveniently into three parts. The first is the hilly, rolling area of the northeast with its many small valleys and with bedrock shallow. Most of this area lies at an elevation between 3,150 and 3,250 feet above sea-level. The second division includes the area along Medicine River and in the southeast. The surface of this division is smoother than that of the first, as it has undergone stream erosion, followed by deposition of fairly flat-lying ground moraine, and later by sediments laid down in glacial lakes. This area lies mostly between 3,000 and 3,150 feet above sea-level, the highest parts being most remote from Medicine and Red Deer Rivers. The third division comprises the land lying west and southwest of Medicine Valley. Its northern part is characteristically rolling, with hills 10 to 25 feet high, whereas the southern part is typically an area of parallel, broad, southeast-trending valleys and rough sand dunes. It lies mostly between 3,200 and 3,300 feet elevation but rises to 3,700 feet in the southwest. The surficial material is thickest in this division.

The largest lake wholly in the area is Cygnet Lake, but an end of Sylvan Lake juts in from the north. No other large lakes are present, and the area, except in the west where swamps are common, is mostly well drained.

Geology

The entire area is mantled by various thicknesses of drift or alluvium. The bedrock immediately under the drift is Paskapoo formation, and the underlying Edmonton formation is too deep, probably everywhere more than 500 feet, to affect either topography or water supply. The dip of the Paskapoo bed is small and its direction here unknown. Bedrock is exposed along much of Red Deer Valley, in the valley of the Little Red Deer, and, particularly in the northeast, in many road ditches and cuts.

Paskapoo Formation. This formation was first named by Tyrrell from exposures of the lower part of the formation along Blindman River near its confluence with the Red Deer. It is composed essentially of sandstone and shale deposited in fresh water, and includes some thin coal seams and carbonaceous beds. The basal beds are massive, cross-bedded sandstone that weathers buff-yellow, and 150 to 200 feet above the base of the formation are a series of lenses of siliceous limestone containing fossil gastropods and pelecypods. The upper beds are uneven layers of sandstone, commonly uncemented, and shale, that thicken and thin repeatedly. In this area the sand is commonly coarse, reflecting the nearness of the western mountains, and weathers buff-yellow or reddish brown. In several localities the formation seems to contain a greater proportion of shale than is general, and coal seams are of minor importance. Siliceous limestone beds are important only in the west, where they are nearer the surface.

Surficial Geology. During Pleistocene, or Glacial, time great accumulations of ice formed at various centres in northern Canada. This ice moved out in all directions from these centres and covered large regions with what has been called the continental ice-sheet. As the ice advanced, it picked up great quantities of loose rock debris that was left when the ice finally melted. This material is unconsolidated, and is commonly called glacial drift.

The present area was entirely covered by one or more continental ice-sheets during Pleistocene time, and the final retreat of the ice left the bedrock buried to various depths by glacial drift. Most of the drift consists of boulders and pebbles of various compositions and sizes embedded in a matrix of clay or sandy clay to form a more or less impervious mass known as boulder clay or till. Irregularly intermingled with this till, and also lying above it, are beds, pockets, and lenses of sand and gravel that form the water-bearing members or aquifers.

The till of the area is light brown, reddish brown, or grey. It generally contains much clay and is practically impervious to water but locally may contain considerable sand, especially in the northeast where bedrock is shallow. The few stones present are mostly quartzite or sandstone pebbles, originally brought from the west by rivers and later redistributed by the ice. Large boulders are rare. Igneous and metamorphic stones brought by ice from the northeast, although present, are not common. Traces of older till are present in the valley of Red Deer River, and also in old, filled valleys, where they have been protected from subsequent glacial erosion. This older till is of darker colour than the younger, and is more compact and sticky.

Gravel is common in the southwest and along some rivers. It consists mostly of material originally brought from the west by streams, much of which was transported again by water and ice in interglacial and post-glacial times. It is generally coarse, and has all degrees of sorting and bedding.

The surficial material in the area has an average thickness of probably 15 to 20 feet. It is thinnest in the northeast, where it averages about 5 feet in thickness, and thickest in the west and southwest, where in several old river channels it may be more than 100 feet thick.

Ground Moraine. This type of glacial drift is chiefly till or boulder clay laid down beneath the ice-sheet. In this area it consists of the till described above and, particularly in the west, contains a few lenses and pockets of water-lain sand and gravel. It commonly has a gently to strongly rolling surface. Ground moraine, chiefly in large patches in the northeast and in the west, covers about 260 square miles of the area.

End Moraine. Part of the material carried by the ice-sheet was dropped at its front or margin during pauses in the general retreat of the melting glacier. It consists of till, silt, sand, and gravel gathered during the advance of the ice-sheet. Much of the clay, silt, and fine sand was carried away by melt-water from the glacier, and the material forming end moraine is commonly coarser than that of ground moraine. Much of it consists mainly of gravel, sand, and coarse till, characteristically arranged in hummocks and undrained or poorly drained hollows.

Only a few linear ridges of end moraine and some patches in a valley in township 35, range 1, occur in this area. Some of the north-western part of the area mapped as ground moraine is hummocky and contains undrained hollows. It is perhaps low end moraine.

Glacial-lake beds. During the melting back of the ice-sheet many lakes were formed where the normal drainage was temporarily blocked by lobes of ice or masses of glacial debris. The sand, silt, and clay washed into these lakes was exposed upon the draining or lowering of these lakes. Similar, although commonly coarser, material was laid down by streams draining these lakes or running out of the melting ice, and by recent streams. About 200 square miles of the area, mostly in the valley of Medicine River, are covered by such beds, which are commonly underlain by ground moraine.

Alluvium. Rivers and streams commonly have bordering regions in which, during times of flood or through shifting of the river channels, gravel, sand, silt, and clay are deposited. Such material is present not only along the present rivers, but in the abandoned valleys of rivers that have since disappeared. Much of the older alluvium has been reworked by ice, and may contain pockets of till or be overlain by layers of ground moraine.

Alluvium is particularly widespread in this area and covers 80 to 85 square miles. To the west the land is mountainous and the streams have a high gradient. In the Markerville area the gradient decreases, causing the streams to drop much of their load.

Sand Dunes. In some localities the lake and alluvial sand or silt has been reworked by wind action, and commonly formed into sand dunes. These dunes are mostly longitudinal ridges, 10 to 40 feet high, which trend northwestward. Altogether such deposits cover about 40 square miles.

Water Supply

With the exception of a few small districts to be mentioned later, sufficient water for ordinary farm and town use can be obtained anywhere in the area. The quality is generally good, and chemical analyses of representative samples are given later.

The average depth of drilled wells in the area is about 105 feet, being greatest towards the centre of the area and shallowest in the north. The water is generally under pressure and, although its rise in the wells is extremely variable, it generally rises one-third to two-thirds of the distance to the surface. Springs occur along some valleys, and several flowing wells are present, particularly in the northwest.

The average yearly precipitation in the area ranges from about 17 to 22 inches, being greatest in the southwest and least in the northwest and southeast. One-quarter to one-third of the precipitation is in the form of snow. The eastern half of the area is generally well drained, but has many trees and a moderate run-off. The west is commonly poorly drained and heavily wooded, and, consequently, the run-off is slow and proportionately small. The alluvium, sand dunes, and to a lesser extent the ground moraine, will hold water and allow seepage into the bed-rock, whereas the lake clay is nearly impervious to water. Humidity is low, the summers are warm, and evaporation is often high. However, in most of the area, the water available to soak into the ground is many times more than enough to supply all present needs and all foreseeable future ones, and any difficulty that is had in obtaining sufficient water is due to lack of porous aquifer beds rather than to a lack of water to enter them.

Several dependable sources of surface water are present. The chief of these is, of course, the swiftly flowing Red Deer River, but Little Red Deer, Medicine, and Raven Rivers are also sources. A number of other streams in the southwest can also supply some water. Sylvan and Cygnet Lakes contain good, fresh water, which is now being used for cattle. Small, fresh-water ponds are also present, particularly in the southwest.

The alluvium, dune sand, lake sand or silt, and the glacial-outwash gravel are the important water-bearing surface materials, and they generally yield satisfactory supplies. Some wells are sunk in the rolling ground moraine in the western half of the area, but their water supply is rarely satisfactory. Of the 150 non-bedrock wells about 75 draw from glacial drift, 65 from alluvium, and the others chiefly from dune sand. These wells are largely in the southwest of the area. The supply in many of these shallow wells, into surface material, decreased in the dry years of 1949 and 1950, and they largely are being replaced

by deeper, commonly drilled wells, into bedrock. The shallow wells are largely in recently settled areas, or where streams and sloughs offer supplementary supplies for watering stock, or in villages where large supplies are unnecessary. Water found in the drift is mostly hard, as it contains much calcium, and it may also contain noticeable iron. Water from the alluvium is mostly hard or moderately hard, but is soft in several wells.

Of the 795 wells and springs recorded, about 642 draw from bedrock aquifers, in all cases from the Paskapoo formation. About 140 of these 642 are springs, or dug or bored wells, the rest drilled wells. In two of the sixteen townships all the wells recorded tap bedrock aquifers.

The Paskapoo formation generally contains abundant water, mostly in lenses of porous sand that yields water rapidly and that are more common in some horizons of the formation than in others. None of these lenses can be traced far, but in most places they overlap and form aquifer zones. Each of these zones has water with distinguishing characteristics, and some of them are traceable for fair distances. In a few places, however, sand lenses seem to be absent, and the formation is almost entirely clay and shale.

The water contained in the Paskapoo formation of the area varies greatly in quality, but commonly contains much calcium carbonate, indeed some of the water is too hard for ordinary washing. Of those wells into Paskapoo beds recorded, about 223 yield hard water, 154 moderately hard, and about 266 soft. The water of about one-third of the wells contains enough iron to taste or to cause stains. In a few instances much iron is present, although rarely so much as to prevent use of the water.

As the soft water of the area contains much soda, aluminum, or magnesium, casing is inadvisable in wells yielding this type of water.

In the well record sheets at the end of the report, and in the descriptions of the various townships, the terms poor, insufficient, fair, sufficient, good, very good, and excellent, are used to describe the water supply. Poor or insufficient is used if enough water for ordinary farm needs, perhaps 500 gallons a day, cannot be obtained from the well. Fair supply is used if there is enough water for such needs, and generally more than 1,000 gallons a day, but only obtained by slow pumping or by pumping small amounts several times a day. Sufficient supply indicates that enough water is available, but that little information could be obtained regarding the amount used. Good supply is used if the well does not go dry under ordinary farm demands, and if enough water for each day's farm needs with some to spare can be obtained at one pumping. Such wells can yield 2,000 gallons a day and commonly as much as 5,000 gallons. Very good supply means that no trouble has ever been had in obtaining sufficient water, and that between 7,000 and 15,000 gallons a day should be available. Excellent supply is used if the amount of water available is exceptionally good.

Township 35, Range 1. Red Deer River, which flows eastward in a valley about 80 feet deep, forms the northern boundary of this township, and Little Red Deer River crosses the east centre. Several small creeks are tributary to these rivers. The surface is flat to broadly rolling, and is generally a bedrock surface slightly modified by overburden. It rises from an elevation of about 2,975 feet at Red Deer River to more than 3,200 feet in the southeast, but mostly it lies between 3,020 and 3,120 feet.

Ground moraine covers the bedrock everywhere in the township but is rarely exposed as it is commonly overlain by a thin mantle of glacial-lake sand or, in the southwest, by wind-deposited sand. Also on the east margin of the township a north-trending valley contains hummocks of end moraine and some sand hills. Though the surficial material, which is thickest in sand-dune areas and thinnest near Little Red Deer River, has an average thickness of only about 15 feet,

actual outcrops of bedrock are recorded only from Little Red Deer Valley.

Some of the surface material, chiefly the sand, can supply small amounts of hard water, but only 5 of the wells recorded obtain their water, a sufficient supply in each case, from this material. As the surface material is thin, attempts to obtain much water from it are generally inadvisable, and most wells tap bedrock aquifers, which are more satisfactory.

Wells into bedrock are 75 to 233 feet deep, with an average depth of 115 to 120 feet, and obtain water from aquifers between 2,840 and 3,070 feet above sea-level. The upper aquifers are used in the high districts lying in the south, and the deeper ones in the low land near Red Deer River. About half the wells, mostly those more than 130 feet deep, yield soft water, whereas those less than 130 feet deep yield hard water that generally contains noticeable to much iron. The amount of water is ample, and most drilled wells could supply 5,000 gallons a day. Although in a few wells the water has no pressure, it generally rises to within 20 feet of the surface. It will rise to more than 3,100 feet above sea-level in the southeast, to about 3,000 feet in the northwest, and to about 2,900 feet in the northeast.

In general, sufficient water for ordinary farm use can be obtained anywhere at moderate depth in the bedrock, and large amounts are commonly available.

Township 35, Range 2. Red Deer River crosses the northwest corner of the township in a valley about 100 feet deep, and the Little Red Deer flows northeastward through the centre in a valley that increases in depth from a few feet in the south to about 80 feet in the north. Except for these valleys, the surface has little relief and is nearly flat to gently rolling. The highest districts, about 3,120 feet above sea-level, are in the southwest, and the lowest, at 3,070 feet, in the northeast, but most of the townships is about 3,120 feet above sea-level.

Alluvial plains about half a mile wide border both sides of the river channels. These are composed of gravel with minor amounts of silt and sand. Sand dunes, up to 15 feet high, form a rough surface to 6 square miles of the southeast. This area is thinly inhabited, mostly wooded, and contains many sloughs. Ground moraine covers most of the remaining area, but in the northeast it is overlain by lake clay and silt, and northwest of Red Deer River by lake sand, silt, and clay. Northwest of Red Deer River the average thickness of surface material is probably about 40 feet and between Red Deer and Little Red Deer Rivers about 20 feet. It is thickest in the sand-dune areas of the southeast.

Of the wells examined, 8 draw small amounts of hard water from glacial drift, chiefly ground moraine, and 7 from alluvium, chiefly the river gravel. The latter yields a fair supply of water, mostly hard, that varies considerably from season to season. Generally, however, wells into the surface material are not satisfactory. Bedrock is a more dependable source of water, and 35 of the wells recorded draw from it.

Most of the bedrock wells are drilled, and are 60 to 220 feet deep, with an average depth of about 115 feet. Those that yield the most water tap aquifers between 2,890 and 3,065 feet above sea-level, but mostly between 2,985 and 3,065 feet. Practically all yield soft or moderately hard water, and generally the lower the aquifer the softer the water it contains. The few wells with hard water have an insufficient supply gathered mostly from surface seepage, and this water contains noticeable to much iron. Although several of the drilled wells can yield much water, the supply in general is only fair, and that from aquifers at elevations between 2,900 and 2,980 feet and those above 3,030 feet is apt to be small. The supply of water southeast of Little Red Deer River is commonly good, between Red Deer and

Little Red Deer Rivers poor to fair, and northwest of the Red Deer generally poor. The bedrock water nearly everywhere is under enough pressure to rise in the wells half the distance to the surface; to about 3,150 feet above sea-level in the southwest and to 3,000 feet in the northeast.

In general in this township, drilled wells into bedrock are advisable, and most of these will obtain adequate amounts of soft water at moderate depth. If more water or softer water is required it is generally available at greater depth.

Township 35, Range 3. Red Deer River, which flows eastward through the centre of the township in a valley about 100 feet deep, drops from about 3,200 feet to 3,100 feet above sea-level in crossing the township. Raven River enters it in section 28. The old meanders, channels, cut-offs, and flood plains of the Red Deer and the valleys of other old streams, which mostly trend northwestward, characterize the areas south and west of Red Deer River and cause a rough and irregular surface, whereas north of Red Deer River the surface is undulating to rolling. The surface has a drop from about 3,250 feet above sea-level in the west to about 3,160 in the southeast, and to less than 3,100 feet in the northeast.

Ground moraine covers the entire area north of Red Deer and Raven Rivers, but in the extreme northeast corner it is overlain by glacial-lake sand. South of Red Deer River ground moraine covers several square miles, but most of the surface material is river alluvium, consisting of gravel, sand, silt, and clay, intermingled with patches of till and outwash gravel. Wind has duned much of the sand. This alternation of alluvium and till continues west of the Red Deer, and altogether covers nearly half the township.

As the surficial material is generally thicker than in any of the other townships, little information on the depth to bedrock is

available. It is exposed in the south of sections 2 and 3, and along Red Deer River, but elsewhere it is deeply buried, especially where old valleys have been filled. Alluvium, including gravels of preglacial, interglacial, and post-glacial age is present, along with gravel gathered up by ice and later deposited as outwash. Till is common, and patches of old till, overlain by younger till and alluvium, may be seen in valleys. The alluvium in Raven Valley and around Dickson seems to be especially thick, but the lessening gradient of the swift-flowing streams from the mountains has aided deposition of alluvium everywhere.

As much sand and gravel is present and as the area has only recently been settled, most wells are dug and are shallow. In all 33 dug wells and several springs are recorded, most of which have sufficient, but commonly hard, water. A few have a large amount of water, but the supply in several is insufficient. They average 20 feet in depth, and mostly tap aquifers in alluvial gravel, except near Dickson where aquifers in either alluvium or lake sand are used. During the past dry summers (1949 and 1950) the water supply of most of these wells decreased, and many are being replaced by deeper, drilled or bored wells. Most dug wells near Dickson yield ample water, much of which, unfortunately, contains so much iron as to prevent its use.

Of all wells recorded 23 tap bedrock aquifers, 21 draw from alluvium, and 7 from glacial drift. The 17 drilled wells recorded, 16 of which enter bedrock, all yield ample water. The drilled wells are from 45 to 175 feet deep, with an average depth of 90 feet, and tap aquifers anywhere between 2,990 and 3,170 feet above sea-level. The water is soft in those wells deeper than 90 feet, but hard in those less than 80 feet deep, 8 of the 9 soft-water wells being drilled into bedrock. The hard water generally contains noticeable iron, and in some places much of it. The water

in the drilled wells has generally enough pressure to rise about half way to the surface.

In general, although shallow, dug wells, especially those in alluvium, may yield sufficient water, larger and more dependable supplies of better water are available at greater depth, particularly from moderately deep wells drilled into bedrock.

Township 35, Range 4. From an elevation of 3,700 feet above sea-level in the west, the surface of this township falls rapidly northward and eastward to an elevation of 3,500 feet in the northwest, 3,200 feet at Red Deer River in the southeast, and to a low of about 3,150 feet at Raven River in the northeast corner. The township, which is largely wooded with pine, spruce, poplar, and birch, has many rapid, clear streams, and is crossed by several generally broad, dry valleys with a southeast trend. The surface is characteristically rough, rolling, and hilly.

The average thickness of the surficial mantle is perhaps 20 or 30 feet, but as few wells go right through it, the depth of bedrock is generally unknown. In this region swiftly flowing streams from the west have deposited much gravel in preglacial, interglacial, and post-glacial times. Some of the earlier of these gravels was picked up by the ice and redistributed as outwash gravel or mixed with till. As a consequence of these processes, gravel may be found both overlying and underlying till and is probably present between older and younger till sheets. It shows every variation in size of pebbles and degree of sorting.

Eighteen square miles of ground moraine are shown on the map, but much of it is underlain by gravel. About 14 square miles are shown as alluvial gravel, sand, and silt, which, however, contains pockets of till. Wind has reworked the alluvial sand and silt to form an area of sand dunes, some as high as 30 feet, covering 4 square

miles. Most of this area, also, is underlain by gravel. Thus, most of the township has at least one gravel bed above bedrock, and these gravel layers are generally 6 to 14 feet thick.

As few drilled bedrock wells are present, little is known of their value. The 6 recorded are 55 to 155 feet deep, with an average depth of 110 feet, and tap aquifers between 3,100 and 3,480 feet above sea-level. The 2 wells that tap the lower aquifers yield soft water, but the others hard. The supply in all 6 is good. Drilled bedrock wells should obtain ample water anywhere at rather shallow depths.

There are 21 dug wells and several springs in the township. The dug wells average 20 feet in depth and all yield hard or moderately hard water. In about half, the water contains noticeable to much iron. The supply is generally good but is insufficient in a few cases. During the dry summers of 1949 and 1950 the supply decreased noticeably, and deepening the wells would be beneficial in most cases. As local relief is high, the water-table is very irregular. It stands at about 3,550 feet above sea-level in wells in the southwest, at 3,400 feet in the northeast, at 3,200 feet in the southeast, and at 3,150 feet in the northeast. The rise in the wells is generally small and commonly negligible, but the water rises half way to the surface in rare instances.

Of the 21 non-bedrock wells and springs, 18 obtain water from gravel. Although use of bedrock aquifers should increase, gravel will continue to supply much of the water used. As many streams are available for cattle, and the gravel and sand areas are poor farmland, the demand for underground water may never be great in this township.

Township 36, Range 1. Red Deer River flows eastward along the southern boundary of the township, but just beyond the eastern boundary it swings north. Medicine River flows across the southwestern corner of the township in a shallow, broad valley, and its tributary, Tindastou Creek, occupies a large valley crossing the northwest corner. The surface of the township, which is mostly flat to undulating, drops from about 3,100 feet above sea-level in the northeast and 3,000 feet in the northwest to 2,940 feet near Medicine River in the southwest, and slightly lower in the southeast.

A thin mantle of glacial-lake clay, silt, and sand covers most of the township, but patches of the underlying ground moraine project through it in many places, and in the southeast the lake beds have been entirely eroded away. The meander belts of Red Deer and Medicine Rivers cover about 4 square miles in the southwest. The following is a generalized section through the surface material near Medicine River. A thin layer of gravel overlies bedrock, overlain by some sand that is in turn overlain by a thick bed of silt and clay. Farther from the river the basal gravel is missing and still farther the sand also is absent. In the eastern part of the township lake clay lies directly on till.

The average thickness of the surface material is about 15 feet. It is greatest in the alluvial gravel and silt near the junction of Medicine and Red Deer Rivers, and in the thick lake bed along Medicine Valley, and is least in the southeast and north.

The 6 non-bedrock wells recorded are near Medicine River in the southwest, and either draw their water from alluvium or from gravel and sand below the lake clay. They yield hard water in only poor to fair amount, and supplementary sources of water, such as the river or springs, are necessary for stock. The thinness and impermeability of the lake clay and till render any attempt to obtain water in them useless.

Most of the wells, including all soft water ones, enter bedrock, but the shallow, dug ones rarely have sufficient water, whereas the yield of all the drilled ones, which are 65 to 195 feet deep with an average depth of about 110 feet, is sufficient or good. In sections 10, 11, 13, 14, 15, 22, 23, 24, 25, 26, 27, 34, 35, 36, or in the northeast where the surface is highest, aquifers between 2,940 and 3,000 feet above sea-level are used, whereas elsewhere aquifers between 2,850 and 2,920 feet are tapped. About equal numbers of wells yield soft, moderately hard, or hard water, and the same aquifer may supply soft water in one area and hard in another. The hard and moderately hard waters generally contain noticeable to much iron. The water in most of the drilled wells has enough pressure to rise two-thirds to three-quarters of the distance to the surface, that is, to nearly 3,100 feet elevation in the northeast and to nearly 3,000 feet in the northwest, to less than 2,940 feet in the southwest, and to less than 2,900 feet in the southeast.

In general, drilled wells are best, and ample water may be obtained at rather shallow depths anywhere in the bedrock.

Township 36, Range 2. Red Deer and Little Red Deer Rivers occupy valleys about 80 feet deep. Medicine River flows in a broad, shallow valley. The surface of the township, most of which is flat to gently rolling, rises from about 2,950 feet above sea-level near Medicine and Red Deer Rivers to more than 3,000 feet in the northeast, to 2,980 in the north centre, to 3,150 in the northwest and west, and to about 3,110 feet in the southwest. Lake beds overlie nearly the entire township, forming a black soil and giving a characteristically flat surface. Mostly they consist of clay, but sand and silt predominate in the southeast. However, large patches of the underlying ground moraine appear where the lake sediments

have been removed or were never deposited. As the lake beds are commonly thin, and in places only a few inches thick or even missing, the surface generally reflects the undulating to rolling topography of the underlying ground moraine. Where both ground moraine and lake deposits are thin, as in the northwest, broad, gentle, bedrock swells control the topography. Alluvial gravel occurs near Red Deer River and alluvial silt and sand near Medicine River. In the northeast part of the township wind has formed northwest-trending, longitudinal sand dunes, mostly 10 to 20 feet high. The surficial material is generally 10 to 20 feet thick, but in areas of sand dunes and alluvium it is thicker and may be as much as 80 feet thick in the southwest, where an old valley has seemingly been filled with alluvium.

Three-quarters of the wells draw water from bedrock, and two-thirds are drilled. The non-bedrock wells are largely confined to the alluvium area of the southwest, near the alluvium and sand-dune districts in the northeast, and in the north where several obtain water from near the contact of overburden and bedrock. They yield hard or moderately hard water, which in places contains noticeable iron. The supply is rarely more than just sufficient and is commonly poor, and in several of these wells decreased in the dry years of 1949 and 1950.

The drilled bedrock wells are from 55 to 190 feet deep, but mostly between 80 and 120 feet with an average depth of about 110 feet. They tap aquifers between 2,850 and 3,050 feet above sea-level, the lower aquifers being used in the east and the higher in the southwest and northwest. About three-quarters of these wells yield soft or moderately hard water, and iron is noticeable in the water from about only one-fifth. Although the amount of water is generally good, in three areas sufficient water is difficult to

obtain. The first area, in sections 24 and 25, obtains adequate water but with none to spare at about 2,870 feet. The second area is in the north of section 21 and in the south of sections 28 and 29, where only fair supplies are obtained from aquifers at about 2,920 feet. Deeper drilling should improve the supply in this area. The third area, which is more complex, is in sections 8, 9, 10, 16, 17, and 18, with the poorest supply in the east of section 8 and in section 16. The cause of the scarcity of water in three areas is uncertain, but may be in part that there is a greater proportion of clay and shale in the bedrock there than normal. In the third area, however, another factor may be the principal cause. Apparently an old valley, perhaps a former course of Raven River, crossed the southwest part of the township. This valley has been filled with alluvium and till, locally as much as 150 feet deep, and into it much of the water in the bedrock nearby may be draining. This reduces the likelihood of good supplies of water being obtained from the bedrock but means that the lower part of this valley may be a potential source of large supplies of water. In these areas of difficult water supply, the likelihood that deep drilling may be necessary should be borne in mind, and the well should be located as far to the north as possible.

The water in bedrock aquifers is generally under enough pressure to raise it one-half to four-fifths of the distance to the surface, and it rises above 3,100 feet elevation in the west centre, above 3,050 feet in the northwest and southwest, above 2,950 feet in the northeast, and to about 2,950 feet near Red Deer and Medicine Rivers.

In general the surface material is unsatisfactory as a source of water, whereas most wells into the Paskapoo formation, especially those drilled to depths of 100 feet or so, yield ample

water. However, deep drilling is necessary in several areas if large supplies are required.

Township 36, Range 3. The surface of this township rises steadily from east to west from an elevation of about 3,110 feet to over 3,200 feet, and in places over 3,250 feet above sea-level. Lake waters have covered the extreme eastern edge of the township where the surface is more or less flat, but as the surface rises to the west and there is less modification by the glacial-lake waters, it becomes more irregular until near the western border there are broad, rolling hills 3 to 10 feet high. An old valley, which now contains no stream although it is as much as 50 feet deep, trends southward through the centre, and is marked by swamps, peat bogs, and some fine gravel.

Lake beds of clay and silt in the east and sand in the southeast cover about 7 square miles, and a few sand dunes, 20 or 30 feet high, are present in the extreme southwest corner. Rolling ground moraine is the surface material elsewhere. The surficial material has an average thickness of 15 to 20 feet, but in the south, where an old valley has apparently been filled, it is much thicker.

The supply of water in the ground moraine and lake clay is negligible, and in the northern third of the township only one well is recorded that derives water from ground moraine. Several wells draw water, which is mostly hard and may contain noticeable iron, from the lake sand near Dickson or from gravel in the valley in the centre of the township, but the supply is rarely good, and in more than half the wells is insufficient for local farm needs. The alluvium in the old, filled valley in the south may hold much water, and one soft-water well in the northeast of section 16 probably draws from it. Other wells in southwest section 15, southeast section 13, and northeast section 17 probably also draw water from this buried valley.

The drilled bedrock wells are from 60 to 275 feet deep, with an average depth of 115 feet, and tap aquifers between 2,865 and 3,150 feet above sea-level, but mostly between 2,980 and 3,110 feet. Wells in the higher districts in the west generally use the upper aquifers. Three-quarters of the wells yield soft water, the hard water coming mainly from aquifers above 3,090 feet, and one-quarter of the wells yield water with noticeable iron. The supply, almost without exception but especially in the lower aquifers, is good. However, in northeast section 33, bedrock water is scarce, and 6 wells, 130 to 350 feet deep, have been drilled without the hoped for results. The cause of this local shortage is unknown, but may be due to fewer sand lenses than usual in the bedrock. The water in bedrock aquifers generally has enough pressure to rise two-thirds to four-fifths of the distance to the surface, and it rises to elevations of 3,100 feet in the east, 3,200 feet in the extreme northwest, and above 3,150 feet elsewhere.

In general it is inadvisable to try to obtain water in the surface material but rather to go into bedrock, where ample water, mostly soft, can usually be obtained at moderate depth.

Township 36, Range 4. Raven River flows westward through the centre of the township, occupying only a small part of a large, old valley. Southeastward flowing Stauffer Creek joins it near the centre of the township. Other valleys, also with a southeast trend but now dry, are present. These produce an irregular surface in much of the township, and are commonly marked by swamps, peat bogs, and gravel. Outside the valleys the surface is mostly rolling, with broad, gentle hills 4 or 5 feet high in the northeast, and as much as 30 to 40 feet high in the south. From Raven River in the southeast, at about 3,150 feet above sea-level, the surface rises to about 3,250 feet in the northeast and 3,275 feet in the northwest.

Rolling ground moraine covers about 12 square miles of the southeast. The rest of the township is covered with alluvial gravel, sand, silt, clay, and glacial till, deposited by existing streams in flood plains, meander belts, and channels, by glacial streams from reworked glacial materials, by preglacial streams cutting their large valleys, and by ice mixing up the earlier deposits and adding new material. Wind, blowing across areas of alluvium, deposited sand over most of the area, and tended to flatten out irregularities in the surface. In section 2, however, it formed dunes 40 feet high, and in sections 18 and 19 northwest-striking, longitudinal dunes as much as 20 or 30 feet high have been formed. The thickness of the surficial material is generally unknown, but probably averages more than 30 feet.

As the regions of sand dunes, flood plains, and alluvium are poor farmland and are largely wooded with pine and spruce, most of the township is thinly populated, and information on water supply consequently scanty. About half the wells are dug and half drilled, and most enter bedrock. The proportion of drilled wells may be expected to increase, as they are easier to maintain and yield better water in more satisfactory amounts.

The few non-bedrock wells recorded are chiefly in dune sand or alluvium. They tend to silt up and yield poor to fair supplies of hard water, that is commonly of poor quality and may contain noticeable iron. Bedrock wells, and especially those drilled, are generally more satisfactory. At present they are used in only a small district, but all have ample water that is characteristically soft or moderately hard and that rarely contains noticeable iron. They are 50 to 165 feet deep, with an average depth of 110 feet, and tap aquifers between 3,010, and 3,240 feet above sea-level, but mostly between 3,040 and 3,200 feet. The

upper aquifers are used in the higher areas in the north and northwest. The water is generally under enough pressure to rise one-half to three-quarters of the distance to the surface, that is, to about 3,150 feet elevation in the southeast, 3,200 feet in the northeast, and to above 3,250 feet in the northwest. Drilled wells anywhere in the township should be able to obtain ample water from the bedrock

Township 37, Range 1. The broad valley of Tindastou Creek runs southwest across the centre of the township, dropping from 3,050 feet above sea-level in the northeast to 3,000 feet in the southwest. The land rises to 3,100 or 3,150 feet in the southeast and to 3,230 feet in section 21 and in the northwest. In the south the surface is gently rolling but in the higher land to the north it is irregular and strongly rolling, and is characterized by broad, bedrock hills little modified by drift.

Lake beds, mostly clay that is commonly varved and stony, cover about 9 square miles in the southwest. They are, however, thin, and patches of the underlying ground moraine are exposed in many places. Ground moraine, rarely more than 10 feet and commonly not over a few inches thick covers the remainder of the township, including all the high land. The composition of the till varies in accordance with the nature of the underlying bedrock, it being sandy where bedrock is sandy and clayey where bedrock is clayey, and its colour is the reddish brown of the Paskapoo sandstone. The thinner the drift, the more it resembles the bedrock. Bedrock outcrops in many road ditches, but is generally covered by 3 to 10 feet of drift, more in areas of lake beds, and by the greatest thickness in the east.

The 2 wells that do not enter bedrock yield insufficient hard water and, as the drift is everywhere thin, practically no possibility exists of finding sufficient water in it.

Two-thirds of the wells are drilled, and these are 16 to 350 feet deep, with an average depth of 120 feet. The 350-foot well obtains its water at 200 feet. The wells tap aquifers between 2,840 and 3,140 feet above sea-level, but mostly in the zone 2,955 to 3,110 feet, and the higher aquifers are used mostly in the northwest. Practically all the drilled bedrock wells yield soft or moderately hard water, whereas the dug bedrock wells mostly yield moderately hard or hard water. Most water from aquifers above 3,010 feet is hard or moderately hard, that from lower ones is soft. Iron is rarely noticeable in the water. Almost all bedrock wells, whether drilled or dug, yield ample water, and if the supply in any well is poor it is generally the fault of the well rather than absence of aquifers. The rise of the water in the wells is variable, and ranges from practically none in the north to three-quarters of the distance to the surface in the south. It rises to about 3,000 feet above sea-level in the southwest, less than 3,050 near Tindastou Valley, to more than 3,100 feet in the southeast, and as high as 3,150 feet in parts of the northwest.

In general, bedrock is the only dependable source of water supply and yields ample water anywhere.

Township 37, Range 2. Medicine River flows southeastward, with low gradient, a narrow channel, and much meandering, in a broad, old valley running through the centre of the township. An old channel of this river is present several miles to the east of its present one, and the land between the two is low. Most of the township is an old lake bed and the surface is mostly flat to undulating. Long, northwest-trending, dunal ridges, mostly 10 feet high but in places as much as 30 feet high, occur near the river, and in the steeply rising, high land in the northeast, broad, bedrock hills modified by small, rolling drift hills 2 to 10 feet

high are characteristic. Near the river the surface is 2,980 to 3,000 feet above sea-level, but rises to more than 3,050 feet in the southwest and to 3,250 feet in the northeast.

The area of about 4 square miles between the river's present and previous channels is covered by sand and fine gravel, such as is present near the modern river. Ground moraine, a few inches to 7 or 8 feet thick, covers the bedrock in the northeast. Glacial-lake sediments cover the remainder of the area. These are mostly clay and silt, commonly varved, that contain scattered stones that are fewer near the river and more away from it. The lake beds are generally thin, but are thicker southwest of the river than elsewhere. Scattered patches of the underlying groundmoraine appear here and there at the surface, especially east of the river. In places near the river, alluvium has been reworked by wind, and sand dunes cover an area of nearly 6 square miles. The combined thickness of ground moraine and lake clay is between 3 and 15 feet, and altogether the surface material probably averages about 15 to 20 feet in thickness.

Half of the wells recorded are dug and half drilled. Three-quarters of them tap bedrock aquifers, and half yield soft water. The water rarely contains noticeable amounts of iron. The non-bedrock wells are in sand-dune areas or in alluvium along Medicine River. They require much maintenance and most of them yield hard water. Of the 13 such wells noted, 6 had insufficient water, 5 just sufficient, and only 2 a large supply. The thinness of the ground moraine precludes obtaining water from it, and, as the lake beds have a high clay content, they too are useless for water supply.

The wells drilled into bedrock are 20 to 255 feet deep, with an average depth of 105 feet. They tap aquifers between 2,750 and 3,140 feet above sea-level, although few wells use those

aquifers between 3,000 and 3,100 feet, or below 2,870 feet. Aquifers between 2,970 and 3,000 feet are used mostly by dug wells, largely in the south; those above 3,050 feet are used only in the northeast; and those lower than 2,900 feet are used in the west. Aquifers below 2,970 feet yield soft water, whereas half those higher yield hard water. Most bedrock wells have a fair to good yield of water. From the high land of the northeast water is drained by springs into gullies and lower neighbouring areas. Thus the water here has a negligible rise in the wells, to not much over 3,150 feet above sea-level. Elsewhere it rises to within 20 or 30 feet of the surface, and reaches 3,050 feet in the southwest and about 3,000 feet in other districts.

In general, bedrock aquifers everywhere yield sufficient water for ordinary farm use, but the unconsolidated material is not a reliable source of water.

Township 37, Range 3. Most of the township has an undulating surface that reflects a broad, rolling, bedrock topography. It rises from elevations of about 3,101 feet near Medicine River in the northeast and 3,050 feet in the southeast, to 3,100 feet in the northwest and 3,250 feet in the southwest. The only stream in the township flows eastward across the northern part along a small valley, and the southwest, in consequence, is poorly drained. There the surface is rolling, with small hills 3 to 10 feet high.

Brownish ground moraine is exposed over an area of 11 square miles of the southwest, but over most of the rest of the township it is covered by a mantle of glacial-lake clay, silt, and some sand. The lake sediments are thickest, with the most extensive varving in the northeast, but to the west, near the shore of the old lake they are thin and contain a moderate number of stones. Low sand dunes are the eastern parts of sections 24 and 25. The surface

material is thin, especially in the northwest and north, with an average thickness of perhaps 15 feet. Because of its thinness, and the large amount of clay most of it contains, any attempt to obtain water from the surface material is inadvisable, except perhaps the sand-dune areas, where small amounts of water may be available.

All wells recorded tap bedrock aquifers, and about one-half yield soft water, one-quarter moderately hard, and one-quarter hard water. Iron is rarely present in noticeable amounts. The drilled wells are 60 to 400 feet deep, with an average depth of 115 to 120 feet. They tap aquifers between 2,700 and 3,230 feet above sea-level, but mostly between 2,900 and 3,110 feet, and especially in the zone 2,980 to 3,050 feet. Ninety per cent of the drilled wells, including practically all that tap aquifers below 3,050 feet, yield soft water, usually in fair to good supply. The upper aquifers are used mostly in the higher parts of the township in the southwest. In most of the township those wells with unsatisfactory yields of water tap aquifers higher than those supplying neighbouring wells, and their yields could be increased with a fair amount of deepening. However, most such wells are in the northeast and here the water supply problem is different and more difficult. Nevertheless, here also deepening the wells should help.

The water is generally under enough pressure to rise to within 20 or 30 feet of the surface, that is, to less than 3,000 feet above sea-level in the northeast, to about 3,100 feet in the northwest, and as high as 3,250 feet near the southwest.

In general, the only available water is in bedrock, but this is mostly soft and in fair to good supply.

Township 37, Range 4. Local relief is small in this township, with the lowest elevations, in the northeast, about 3,150 feet above sea-level, and the highest, in the northwest,

about 3,300. The southern half of the township lies at an elevation of about 3,270 feet. Most of the surface is rolling, with broad, drift hills 3 to 10 feet high, but higher, dunal hills are present in the southwest, and the extreme northeast is comparatively flat. Drainage is generally poor, and swamps, many of which contain peat, are common. Several southeast-trending valleys cross the southwest part of the township, but these do not now contain streams.

Ground moraine covers most of the township. In a small area in the northeast, however, patches of thin, clayey lake beds overlie it, and in the southwest sand dunes, mostly in northwest-trending ridges, are present. Along the extinct stream valleys gravel occurs both below and above the till. The surficial material has an average thickness of less than 20 feet.

Most wells are either dug, or dug and later deepened by boring, but about one-third are drilled. About half the wells yield soft or moderately hard water, and iron is noticeable or in large amount in the water from one-third. Three wells, which appear to draw water from the zone at the contact between the drift and bedrock, have insufficient water, and most of the surface deposits, with the possible exception of the dune sand, offer little prospect of large supplies. The bedrock, which is generally shallow, is a better source of water, and practically all wells tap aquifers in it. They use aquifers between 3,070 and 3,270 feet above sea-level, but mostly in the zone between 3,100 and 3,270 feet. The lower aquifers are used in the low land in the northeast, where are most of the drilled wells, whereas the higher aquifers are used in the west. The drilled wells are 30 to 180 feet deep, with an average depth of about 80 feet, and mostly use the lower aquifers. These aquifers yield large amounts of water that is mostly soft or moderately hard. About three-quarters of the dug wells yield hard

water. About half of them have ample water, and the others just enough or else insufficient water. These dug wells mostly tap aquifers over 3,200 feet above sea-level.

The water is under strong pressure, generally rising to within 10 or 15 feet of the surface, and several springs and flowing wells are present. In the northeast it rises to only 3,150 feet above sea-level, but elsewhere to more than 3,250 feet.

Township 38, Range 1. Cygnet Lake and the south end of Sylvan Lake lie in a broad valley crossing the east part of the township. Broad flats, which are at times or were in the past covered by water, border these lakes. Elsewhere the topography shows broad bedrock hills and ridges that are slightly modified by minor, gentle drift hills a few feet high. Cygnet Lake, which, although shallow, is used for watering cattle, is about 3,050 feet above sea-level, and Sylvan Lake is slightly higher. The northeast part of the township rises to an elevation about 3,130 feet and the west centre to 3,250 feet. The centre and northwest lie at an elevation of about 3,150 feet, and the southwest at 3,200 feet.

Lake water covers about 4 square miles of the township. Near the lakes, water has reworked ground moraine to form a flat or undulating surface covered with patches of sand, silt, and clay, of various thicknesses and commonly bedded. The rest of the township is covered by a thin mantle of ground moraine, composed of sandy till containing a few stones and with the reddish brown colour of the Paskapoo formation. Bedrock is, however, exposed at several points. The surface material probably averages less than 10 feet in thickness, although near the lakes its thickness is difficult to determine. Even there, however, it is unlikely to be great. On the hills and higher areas it is rarely more than a few feet thick. Largely because of this thinness, the surficial

material is of little importance in water supply, except in the town of Sylvan Lake. The wells in that town need only yield very small amounts of water for domestic purposes and draw mostly from lake sediment. Outside the town only 2 wells are recorded that draw water from the surficial material, one a poor supply from lake sediment. In both wells the water is hard.

The drilled bedrock wells, which form 90 per cent of the wells recorded, are 30 to 205 feet deep, with an average depth of about 90 feet. They tap aquifers lying between 2,870 and 3,225 feet above sea-level. About half the wells yield moderately hard water, one-fifth hard, and the remainder soft water. Iron is noticeable in the water of about one-quarter. About 85 per cent of the wells recorded yield ample water. In a few the supply is just sufficient, and in 6 not sufficient for ordinary farm needs. In general, the lowest aquifers contain the most, and the softest, water.

The water rises to near the surface in low areas, but not so high in the wells in the high districts of the west and northeast. It is, however, everywhere under pressure, and rises to about 2,950 feet above sea-level near Cygnet Lake, to more than 3,100 feet in the northeast and northwest, to about 3,150 feet in the southwest, and above 3,200 feet in the west centre.

In general, most bedrock aquifers, which are the only reliable sources of water, yield soft or moderately hard water in good supply.

Township 38, Range 2. The shallow, meandering channel of Medicine River cuts southwards through the southwest corner of the township in a broad valley, which, however, is narrower here than farther south. From about 2,980 feet above sea-level near the river the land rises fairly steeply eastwards, to about 3,170 feet at Benalto, and to more than 3,200 feet 2 miles east of Evarts. East

of these points the surface levels off and the northeastern two-thirds of the township lies between 3,200 and 3,250 feet.

The surface near the river is more or less smooth, but in those districts remote from the river, above 3,200 feet, it is rough, hilly, and swampy, and is much dissected by valleys. Bedrock, slightly modified by broad, gently rolling, morainal hills 3 to 8 feet high, shapes the topography of the higher districts.

Alluvium and lake sediment, mostly clay and silt but including some sand, covers Medicine Valley, and ground moraine covers the remaining area. Altogether, the surficial material probably does not average much more than 10 feet in thickness. It is thickest in the areas of alluvium and lake sediment but is only 5 to 10 feet thick on the slope rising eastwards from the river, 5 feet thick near Benalto, 2 to 15 feet thick in the central regions, and generally less than 5 feet thick on the slope towards Sylvan Lake.

As it is thin, the ground moraine does not yield much water, and even the alluvium and lake sediment can give only small, variable quantities of hard water from wells that would require much maintenance. Probably all the wells recorded tap bedrock aquifers, which are more satisfactory and dependable than those in surface material.

A few dug or bored wells are recorded, and these yield sufficient water for farm needs, but do not supply as much water as the deeper, drilled wells. Most wells are drilled, and are 30 to 160 feet deep, with an average depth of about 95 feet. They tap aquifers between 2,850 and 3,230 feet above sea-level. The lowest aquifers are used in the low areas of the southeast, those above 3,200 feet are used in sections 10, 11, and 15, and mostly those about 3,170 feet are used in the northeastern half of the township. The yield is good in all but one well. This well, in northeast section 25, taps an aquifer that is drained by lower ground in the east, and deepening is

advisable. The wells are divided fairly evenly between those that contain soft, moderately hard, and hard water, with the lower aquifers supplying most of the soft water. The water of one-quarter of the wells contains noticeable iron. The water is under some pressure but, because many aquifers are drained by low-lying areas nearby, its rise in the wells is extremely variable and is generally less than in other townships. It rarely rises more than half way to the surface, but springs occur on both the slope towards Sylvan Lake and that towards Medicine River. The water does not rise to 3,000 feet in the southwest near Medicine River, but rises to 3,150 feet above sea-level in the southeast and northeast, and above 3,200 feet in most of the remainder of the area.

Township 38, Range 3. Medicine River flows southward across the northeast corner of the township. It occupies a shallow, meandering channel in a valley that, although several miles wide, is narrower here than farther south. From the river the land rises steeply eastwards from 2,980 feet at the river to more than 3,100 feet, and in places more than 3,150 feet, above sea-level in the northeast. Westward the land rises less abruptly to 3,140 feet in the northwest, 3,120 feet in the southwest, and more than 3,200 feet in sections 18 and 19. Generally the surface is undulating to gently rolling, and the main features of the relief are controlled by bedrock.

Alluvium is present beside the river, but elsewhere a thin mantle of ground moraine overlies bedrock. Much of this ground moraine is in turn overlain by patches of lake sediment mostly composed of clay or silt, commonly varved, which modify and smooth out its rolling surface. It is noteworthy that in parts of the southwest till overlies the lake beds.

The surficial material has an average thickness of probably little more than 15 feet. It is thickest in the north, near Medicine

River in the northeast, and in what is probably a filled river valley in sections 22 and 27. In the centre and south it ranges from a few inches to about 20 feet thick, but mostly around 10 feet.

Two drilled wells, in southwest section 27 and northwest section 22, seem to obtain their water from drift and alluvium in an old, buried river channel, and 2 other wells probably draw from ground moraine. These 4 wells yield ample, hard water. Although some water may be obtained from alluvium near Medicine River, or from silty and sandy lake beds, bedrock aquifers are better and, indeed, the thinness of the surficial material commonly leaves no alternative.

Practically all the wells are drilled, are 35 to 165 feet deep, with an average depth of 100 feet, and tap aquifers between 2,830 and 3,140 feet above sea-level, but mostly scattered through the zone 2,900 to 3,120 feet. The lowest aquifers are used in the low land of the southeast and, to a lesser extent, in the northeast. In general, section 1 uses aquifers below 2,900 feet, the western half of the township and section 36 use aquifers above 3,000 feet, and sections 18, 19, and parts of 7 and 20, use ones above 3,100 feet. A few wells yield moderately hard water, the others are about equally divided between those yielding soft and hard water, with most of the soft water being drawn from below 2,990 feet. The supply is generally good, and in the two instances where it is poor, either slight deepening is needed or the wells themselves may be poor. The water from half the wells contains noticeable to much iron.

The rise of water in the wells is extremely variable. In some wells it reaches the surface, whereas in others it scarcely rises at all. It rises to 3,000 feet above sea-level near Medicine River and in the southeast part of the township, to 3,100 feet in the northeast, to above 3,100 in the northwest and southwest, and

to 3,150 feet in the west centre.

Township 38, Range 4. Several small, unimportant streams flow to the north and east. Drainage is generally poor in this township, however, and small ponds, sloughs, and swamps are numerous. Some of the swamps contain peat. The surface of the township, except for more or less flat regions in the northeast and southeast, is strongly rolling, with hills averaging about 10 feet in height and some high points 15 feet or occasionally over 20 feet high. The land rises steadily westward from about 3,100 feet above sea-level in places in the northeast and southeast and 3,150 in the east centre, to nearly 3,200 feet in the northwest and 3,300 feet in the southwest. Bedrock controls the steady, westward rise, but most relief features are formed by drift.

Ground moraine, which is in places almost ~~low~~ end moraine, covers most of the township, but patchy lake clay covers about 4 square miles of the more level regions in the east. The surficial material probably has an average thickness of less than 20 feet.

Seven of the wells recorded yield hard or moderately hard water from ground moraine, which commonly seeps into the well from nearby swamps. Of these wells 2 have insufficient water, 2 just sufficient, and 3 ample water for ordinary farm needs. The water supply in shallow wells decreased during the dry summers of 1949 and 1950. Many of these wells have now been replaced by drilled wells, and others have been deepened by digging or by boring with augers. Generally wells in the drift are unsatisfactory and most wells in the township tap bedrock aquifers. About three-quarters of the wells, including some originally dug and later deepened, are drilled or put down by auger. Most bedrock wells yield sufficient water. The drilled and augered wells are 25 to 200 feet deep, with an average depth of about 80 feet, and tap aquifers between 2,970 and

3,250 feet above sea-level, but mostly between 3,060 and 3,250 feet. In sections 7, 8, 9, 17, 18, and parts of 4, 5, 6, 16, and 19, aquifers above 3,200 feet can be used, but in the extreme northeast, and in part of section 32 and parts of sections 1, 12, and 13, wells have to go below 3,100 feet above sea-level. In the southwestern half of the township aquifers above 3,150 feet can generally be used.

Practically all bedrock wells have ample water, and the only one with insufficient supply is a shallow, dug well from which little water could be expected. There are, however, a few wells with only a fair supply and this could be improved by deepening. One-quarter of the wells yield soft water, and the remainder are equally divided between those yielding hard and those yielding moderately hard water. The water from lower aquifers is no softer than that from higher ones, and the same aquifer may yield soft water in one place and hard in another. Iron is noticeable in the water from about half the wells. The water is under strong pressure. It always has some rise in the wells, and in about two-thirds of them rises to within 20 feet of the surface. Only 9 springs and flowing wells are recorded, but others are present. The water rises to less than 3,150 feet in the northeast and southeast, about 3,175 feet in the northwest, and to more than 3,250 feet above sea-level in the southwest.

ANALYSIS OF WELL WATERS FROM Townships 35-38, ranges 1-4, West of 5th Meridian, Alberta

Constituents as Analysed (parts per million)										Hardness as(CaCO ₃) (pts. per million)									
Sample Number	Section	Township	Range	Meridian	Owner	Depth of well (feet)	Aquifer *	Total dissolved solids (parts per million)	Calcium (Ca)	Magnesium (Mg)	Alkalis (Na,K)	Sulphate (SO ₄)	Chloride (Cl)	Nitrate (NO ₃)	Bicarbonate (HCO ₃)	Alkalinity (as CaCO ₃)	Ca hardness	Mg hardness	Total hardness
4448 NE	10	37	2	5	C. Stevenson	32	P	1234.0	214.8	47.0	15.1	67.5	69.0	197.1	573.0	441.0	535.9	193.4	729.3
4449 SW	1	37	2	5	E. Hehr	176	P	710.0	16.8	8.1	278.4	35.0	10.4	0.0	714.9	586.0	41.9	33.3	75.2
4450 NW	1	37	2	5	R. Youngstrom	42	P	824.0	14.0	7.6	333.2	89.3	17.3	70.9	697.8	626.0	34.9	31.3	66.2
4451 NE	35	37	2	5	D. L. Fitch	145	P	448.0	55.0	31.9	81.2	30.5	0.0	0.0	483.6	306.4	137.2	131.3	268.5
4452 SE	35	38	4	5	J. Dorsti	65	P	396.0	52.1	32.6	59.8	17.3	0.0	0.0	435.7	360.4	130.0	134.1	264.1
4453 SE	4	38	4	5	L. Sebek	28	P	724.0	29.9	8.3	262.4	74.1	0.0	0.0	701.5	575.0	74.6	34.2	108.8
4454 SW	25	38	4	5	W. E. Cole	18	P	378.0	84.0	34.3	12.6	9.9	0.0	3.5	439.4	361.0	209.6	141.1	350.7
4455 NE	25	38	4	5	W. J. Cordan	48	P	378.0	33.2	26.0	86.2	18.9	0.0	0.0	420.9	351.0	82.8	107.0	189.8
4456 SW	5	38	3	5	L. T. Burns	111	P	608.0	2.6	4.4	260.4	14.8	14.8	0.0	615.6	511.8	6.5	18.1	24.6
4457 NW	9	38	3	5	A. Stewart	60	P	576.0	1.4	3.9	244.3	33.7	0.0	0.0	552.2	509.6	3.5	16.0	19.5
4458 SW	26	37	3	5	A. Jarvis	299	P	2526.0	8.9	37.5	920.3	1329.7	0.0	0.0	585.2	616.0	22.2	154.3	176.5
4459 NW	17	38	2	5	R. Hamblly	160	P	630.0	1.1	1.5	268.3	66.3	0.0	0.0	539.7	507.2	2.7	6.2	8.9

* Symbols used for aquifers

P - Paskapoo formation

ANALYSES OF WELL WATERS FROM Townships 35-38, ranges 1-4, West of 5th Meridian, Alberta

Sample Number	Section	Township	Range	Meridian	Owner	Depth of well (feet)	Aquifer	Total dissolved solids (parts per million)	Constituents as Analysed (parts per million)								Hardness as (CaCO ₃) (pts. per million)		
									Calcium (Ca)	Magnesium (Mg)	Alkalies (Na,K)	Sulphate (SO ₄)	Chloride (Cl)	Nitrate (NO ₃)	Bicarbonate (HCO ₃)	Alkalinity (as CaCO ₃)	Ca hardness	Mg hardness	Total hardness
4557	NW 34	38	2	5	H. Lund	80	P	526.0	68.0	32.8	8.7	22.5	0.5	0.4	30.6	238.0	162.7	135.0	504.7
4558	NE 17	38	1	5	E. Grutter	80	P	474.0	83.0	30.6	35.5	16.1	15.0	63.7	427.0	350.0	207.1	125.9	333.0
4559	SW 18	35	4	5	C. Ingram	120	P	374.0	83.0	30.6	13.0	16.4	0.5	0.9	412.4	338.0	207.1	125.9	333.0
4560	SW 15	36	3	5	K. Christiansen	75	P	626.0	31.0	9.8	204.6	68.3	26.5	0.7	483.1	492.0	77.4	40.3	117.7
4561	NW 35	35	3	5	J. Adamsen	75	P	612.0	91.0	39.1	90.1	43.4	11.0	4.4	583.2	478.0	227.1	160.9	388.0
4562	SE 6	36	2	5	R.D. Jensen	68	P	2108	92.0	24.3	616.0	1109.8	6.5	0.9	322.0	428.0	239.5	100.2	329.7
4563	SW 8	35	2	5	M. Cheston	-	A	256.0	74.0	14.6	4.5	5.3	0.5	2.7	278.2	223.0	184.6	60.1	244.7
4588	NW 20	35	2	5	J.L. Smulders	116	P	532.0	21.0	10.3	215.1	61.3	0.5	0.0	485.6	452.0	52.4	42.4	94.8
4589	NE 22	35	1	5	J. Thomson	112	P	658.0	91.0	32.1	115.9	121.0	0.5	0.0	546.6	448.0	227.1	132.1	359.2

* Symbols used for aquifers

P - Paskapoo formation

A - Alluvium

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CANADA
DEPARTMENT OF MINES
AND
TECHNICAL SURVEYS

GEOLOGICAL SURVEY OF CANADA

WATER SUPPLY PAPER No. 318

GROUND-WATER RESOURCES
OF
WILLIAMSBURGH TOWNSHIP
DUNDAS COUNTY
ONTARIO

By

E. B. Owen



OTTAWA

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1951

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INTRODUCTION

This report deals with the ground-water conditions of a township in the province of Ontario investigated by the Geological Survey of Canada. It is one of a series of ground-water reports on individual townships of Ontario.

All available information pertaining to the water wells in the area was recorded and water samples were taken for analysis. The elevation of the surface of the water in most of the wells was measured. As the ground-water conditions are directly related to the geology, the surface deposits were also studied and mapped.

Thanks are here extended to the farmers and to the residents of communities throughout the area for their co-operation and willingness to supply information regarding their wells. Valuable assistance was also given by well drillers and municipal waterworks authorities in the area.

Publication of Results

The essential information pertaining to ground-water conditions is being issued in reports covering each township investigated in the province of Ontario. These reports, as published, will be supplied directly to the proper municipal and township authorities. In addition, pertinent data on wells investigated in each township will be kept on file at Ottawa. The well record compilation sheets will not ordinarily accompany the reports, as, for most areas, they are too numerous. However, persons interested in individual wells may receive the information upon application to the Chief Geologist, Geological Survey of Canada, Ottawa. For this information the request should specify lot, concession, owner's name, and approximate location of the well -- at house, at barn, in pasture, etc.

With each report is a map consisting of two figures. Figure 1 shows the surface deposits that will be encountered in the

area, and Figure 2 shows the positions of all wells for which records are available, together with the class of the well at each location.

GLOSSARY OF TERMS USED

Alluvium. Recent deposits of clay, silt, sand, gravel, and other material deposited in lake beds and in flood-plains of modern streams.

Aquifer. A porous bed, lens, pocket, or deposit of material that transmits water in sufficient quantity to satisfy pumping wells, flowing artesian wells, and springs.

Bedrock. Bedrock, as here used, refers to the consolidated deposits underlying the glacial drift. South of a line drawn between Midland, on Georgian Bay, and Kingston, the bedrock consists mainly of sedimentary rocks such as limestone, shale, slate, and sandstone; north of that line the bedrock consists chiefly of hard, crystalline, granitic rocks.

Contour. A line drawn on a map that passes through points that have the same elevation above mean sea-level.

Continental Ice-sheet. The great, broad ice-sheet that covered most of the surface of Canada many thousands of years ago.

Escarpment. A cliff or relatively steep slope separating two level or gently sloping areas.

Effluent Stream. A stream that receives water from a zone of saturation.

Flood-plain. A flat part in a river valley ordinarily above water, but covered with water when the river is in flood.

Glacial Drift. A general term that includes all the loose, unconsolidated materials that were deposited by the continental ice-sheet, or by waters associated with it. It includes till, deposits of stratified drift, and scattered boulders and rock fragments.

Several forms in which glacial drift occurs are as follows:

(1) End Moraine (Terminal Moraine). A more or less discontinuous ridge or series of ridges consisting of glacial drift that was laid down by the ice at the margin of a moving ice-sheet. The surface is characterized by irregular hills and undrained basins.

(2) Ground Moraine. A widely distributed moraine consisting of glacial drift deposited beneath an ice-sheet. The predominant material is till, which is clay containing stones. The topography may vary from flat to gently rolling.

(3) Kame Moraine. Assorted deposits of sandy and gravelly stratified drift laid down at or close to the ice margin. The topography is similar to that of an end moraine. Kame terraces are elongated deposits of this type laid down on the slopes of broad, flat-bottomed valleys.

(4) Drumlin. A smooth oval hill that has its long axis parallel with the direction of ice movement at that place. It is composed mainly of till.

(5) Esker. An irregular-crested ridge or series of discontinuous ridges of stratified drift deposited by a glacial stream that flowed beneath the continental ice-sheet or in deep crevasses within it. It is composed mainly of sand and gravel.

(6) Glacio-fluvial Deposits. Silt, sand, and gravel outwash deposited by streams resulting from the melting of the ice-sheet.

(7) Glacio-lacustrine Deposits. Clay, silt, and sand deposited in glacial lakes during the retreat of the ice-sheet. The clay deposits are commonly very distinctly stratified in layers a fraction of an inch to one or more feet in thickness; each layer is believed to represent deposition during one summer season and one winter season.

(8) Kame. An isolated mound or conical hill composed of stratified sand and gravel deposited in a crack or crevasse within the ice or in a depression along the ice front.

(9) Marine Deposits. Deposits laid down in the sea during the submergence that followed the withdrawal of the last ice-sheet. They consist chiefly of clay, silt, and sand, and have emerged beaches of sand and gravel associated with them.

(10) Shoreline. A discontinuous escarpment that indicates the former margin of a glacial lake or sea. It is accompanied by scattered deposits of sand and gravel located on former beaches and bars.

Ground Water. Sub-surface water in the zone of saturation below the water-table.

Hydrostatic Pressure. The pressure that causes water in a well to rise above the point at which it was first encountered.

Influent Stream. A stream that feeds water into a zone of saturation.

Impervious or Impermeable. Beds such as fine clays or shale are considered to be impervious or impermeable when they do not permit the perceptible passage or movement of ground water.

Pervious or Permeable. Beds are pervious or permeable when they permit the perceptible passage or movement of ground water, as, for example, porous sand, gravel, and sandstone.

Porosity. The porosity of a rock is its property of containing interstices or voids.

Pre-glacial Land Surface. The surface of the land as it existed before the ice-sheet covered it with drift.

Recent Deposits. Deposits that have been laid down by the agencies of water and wind since the disappearance of the continental ice-sheet; for example, alluvium in stream valleys.

Unconsolidated Deposits. The mantle or covering of loose, uncemented material overlying the bedrock. It consists of Glacial or Recent deposits of boulders, gravel, sand, silt, and clay.

Water-table. The upper limit of the part of the ground saturated with water. This may be near the surface or many feet below it. Water may be retained above the main water-table by a zone of impervious material; such water is said to be perched and its upper limit to be a perched water-table.

Wells. Holes sunk into the ground so as to obtain a supply of water. When no water is obtained they are referred to as dry holes. Wells yielding water are divided into four classes:

(1) Flowing Artesian Wells. Wells in which the water is under sufficient hydrostatic pressure to flow above the surface of the ground at the well.

(2) Non-flowing Artesian Wells. Wells in which the water is under hydrostatic pressure sufficient to raise it above the level of the aquifer, but not above the level of the ground at the well.

(3) Non-artesian Wells. Wells in which the water does not rise above the water-table or the aquifer.

(4) Intermittent Non-artesian Wells. Wells that are generally dry for a part of each year.

Zone of Saturation. The part of the ground, below a water-table that is saturated with water.

GENERAL DISCUSSION OF ~~GROUND WATER~~

Almost all the water recovered from beneath the earth's surface for both domestic and industrial uses is meteoric water, that is, water derived from the atmosphere. Most of this water reaches the surface as rain or snow. Part of it is carried off by streams; part evaporates either directly from the surface and from the upper

mantle of the soil or indirectly through transpiration of plants; the remainder infiltrates into the ground to be added to the ground-water supplies.

The proportion of the total precipitation that infiltrates from the surface into the zone of saturation will depend upon the surface topography and the type of soil or surface rock. More water will be absorbed in sandy or gravelly areas, for example, than in those covered with clay. Surface run-off will be greater in hilly areas than in those that are relatively flat. In sandy regions where relief is great, the first precipitation is absorbed and run-off only commences after continuous heavy rains. Light rains falling upon the surface of the earth during the growing season may be wholly absorbed by growing plants. The quantity of moisture lost through direct evaporation depends largely upon temperature, wind, and humidity. Ground water in areas overlain by pervious material may be recharged by influent streams carrying run-off from areas overlain by relatively impervious material.

Because of the large consumption of ground water in settled areas, it may seem surprising that precipitation can furnish and adequate supply. However, when it is borne in mind that a layer of water 1 inch deep over an area of 1 square mile amounts to approximately 14,520,000 imperial gallons, and that the annual precipitation in this region, for example, is about 30 inches, it will be seen that each year some 435,600,000 imperial gallons of water falls on each square mile. Although it would be impossible to determine the annual recharge of the ground-water supply of the area, if it were assumed that only 10 per cent of the total precipitation, namely 43,560,000 gallons, is contributed to the zone of saturation, it will be seen that the annual recharge for the entire area would be a very large volume. The annual consumption

of water in all areas investigated is not known, but an estimate for some restricted areas, based on per capita consumption, shows it to be only about one-tenth of the annual recharge as estimated above.

In most regions of the world where precipitation is effective there is an underground horizon known as the ground-water level or water-table, which is the upper surface of the zone of saturation. The water-table commonly is a subdued replica of the surface topography. The water that enters from the surface into the unconsolidated deposits and rocks of the earth is drawn down by gravity to where it reaches the zone of saturation or comes in contact with a relatively impervious layer. Such a layer may stop further downward percolation, resulting in perched water and creating a perched water-table. If a water-table is at or near the surface, there will be a lake or swamp; if it is cut by a valley, there will be a stream in the valley. The terms influent and effluent are used with reference to streams and their relation to the water-table. An influent stream flows above the water-table and feeds water into the zone of saturation; an effluent stream flows at or below the water-table and receives water from the zone of saturation. An effluent stream may become influent and eventually dry up if the water-table is lowered sufficiently. The ground water in the zone of saturation is almost constantly on the move percolating towards some point of discharge, which may be a spring or a pumping well.

All rocks and soils are to some degree porous, that is, the individual grains or particles of which they are composed are partly surrounded by minute interstices or open spaces that form the receptacles and conduits of ground water. In most rocks and soils the interstices are connected and large enough for the water to move from one opening to another. In some rocks or soils, however, they are largely isolated or too small to allow movement of water. The

porosity of a material varies directly with the size and number of its interstices, which in turn depend chiefly upon the size, shape, arrangement, and degree of assortment of the constituent particles. Horizons within the earth's crust of fine-grained rock such as shale, limestone or dolomite, or unconsolidated clay or silt, may have such small interstices that the contained water will not flow readily and wells penetrating them may derive little or no water from them. Such horizons are considered impervious. Beds of more coarse-grained materials such as sand, gravel, or sandstone have greater porosity and readily yield their waters to wells. They are called water-bearing beds or aquifers. A clean water-bearing gravel is one of the best sources of water. This is true whether the water is derived from the zone of saturation or from a bed of gravel confined above, between, or below beds of less pervious material.

Consolidated rocks usually considered to be impervious may sometimes produce water in relatively good supply from openings within them of primary or secondary origin. Those of primary origin, original interstices, were created when the rocks came into existence as a result of the processes by which they were formed; e.g. bedding planes, and intergranular spaces. Secondary interstices comprise joints and other fracture openings, solution openings, and openings produced by several processes of minor importance, such as the work of plants and animals, mechanical erosion, and recrystallization; all of these involve movement of a type that acted after the consolidation of the rock. The most important interstices with respect to water supplies are the original interstices, next to them are the fracture and solution openings.

The most common wells and those that in drift-covered areas yield the largest aggregate supply of ground water are water-table wells. These are wells that derive their water from the zone of

saturation. Many shallow wells become dry during the late summer and winter, or during periods of extreme drought. In most cases this is due to the lowering of the water-table below the bottom of the well. The grouping together of a number of water-table wells within a limited area will also lower the yield of any one of the wells. This is especially true of water-producing formations of low permeability. When a well penetrates an aquifer confined by impervious beds, water will be forced upward by hydrostatic pressure exerted at the point where the well enters the aquifer. If the hydrostatic pressure is great enough to force the water to or above the surface, a flowing well is formed.

Springs are formed where the water-table, or some water-bearing aquifer, outcrops at the surface of the ground. The water emerging from water-table springs is free-running water flowing down the gradient of the water-table. In many cases these springs occur as slow seeps along the steeper slopes of stream valleys. A large number in one area could maintain a swamp. A group of permanent springs occurring in one area could provide sufficient water to maintain a lake or form the source of a stream.

GENERAL DISCUSSION OF GROUND-WATER ANALYSIS

The mineral content of ground water is of interest to many besides those industries seeking water of specific quality. Both the kind and quantity of mineral matter dissolved in natural water depend upon the texture and chemical composition of the rocks with which the water has been in contact. Pollution is caused by contact with organic matter or its decomposition products. Analyses of well waters for mineral content are made by the Mines Branch, Department of Mines and Technical Surveys, Ottawa.

In any given area, an attempt is made to secure samples of water representative of all major aquifers. The quantities of the

various constituents for which tests are made are given as "parts per million", which refers to the proportion by weight of each constituent in 1,000,000 parts of water.

The following mineral constituents are those commonly found in natural waters in quantities sufficient to have a practical effect on the value of the waters for ordinary uses:

Silica (SiO_2) may be derived from the solution of almost any rock-forming silicate, although its chief source is the feldspars. It is commonly determined in the analysis of water for use in steam boilers, as silica is classed as an objectionable encrustant.

Calcium (Ca). The chief source of calcium dissolved in ground water is the solution of limestone, gypsum, and dolomite. The common compounds of calcium are calcium carbonate (CaCO_3) and calcium sulphate (CaSO_4), neither of which has injurious effects upon the consumer, but both of which cause hardness and, the former, boiler scale.

Magnesium (Mg). The chief source of magnesium in ground water is dolomite, a carbonate of calcium and magnesium. The sulphate of magnesium (MgSO_4) combines with water to form Epsom-salts ($\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$), and renders the water unwholesome if present in large amounts.

Sodium (Na) is found in all natural waters in various combinations, though its salts constitute only a small part of the total dissolved mineral matter in most waters in humid regions. Sodium salts may be present as a result of pollution by sewage, or of contamination by sea water either directly or by that enclosed in sediments of marine origin. Moderate quantities of these salts have little effect upon the suitability of a water for ordinary uses, but water containing sodium in excess of about 100 parts per million must be used with care in steam boilers to prevent foaming. Waters containing large quantities of sodium salts are injurious to crops and are, therefore, unfit for irrigation. The quantity of sodium salts

may be so large as to render a water unfit for nearly all uses.

Potassium (K), like sodium, is derived originally from the alkaline feldspars and micas. It is of minor significance and is sometimes included with sodium in a chemical analysis.

Iron (Fe) is almost invariably present in well waters, but rarely in large amounts. Salts, or compounds, of iron are dissolved from many rocks as well as from iron sulphide deposits with which the ground water comes in contact. It may also be dissolved from well casings, water pipes, and other fixtures in quantities large enough to be objectionable. Upon exposure of the water to the atmosphere, dissolved iron separates as the hydrated oxide that imparts a yellowish brown discoloration. Excessive iron in water causes staining on porcelain or enamelled ware and renders the water unsuitable for laundry purposes. Water is not considered drinkable if the iron content is more than 0.5 parts per million.

Sulphates (SO_4). Deposits of gypsum ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$) are the principal source of sulphates dissolved in ground water; soluble sulphates, chiefly of magnesium and sodium, are other sources. Sulphates cause permanent hardness in water and form injurious boiler scale. Sodium and magnesium sulphates are laxative when present in quantities of more than 900 parts per million.

Chloride (Cl) is derived chiefly from organic materials or from marine rocks and sediments. It occurs usually as sodium chloride and less commonly as calcium chloride and magnesium chloride. Sodium chloride is a characteristic constituent of sewage and a locally abnormal amount suggests pollution. However, because chlorides may be derived from many sources, such abnormal quantities should not, in themselves, be taken as positive proof of pollution. Chlorides impart a salty taste to water if they are present in excess of 300 parts per million.

Nitrates (NO_3) are of minor importance in the study of ground water. Relatively large quantities in a water may represent

pollution by sewage, or drainage from barnyards, or even from fertilized fields. It is recommended that a bacteriological test be made of water showing an appreciable nitrate content if it is to be used for domestic purposes.

Carbonate (CO_3) forms a large percentage of the solid compounds held in solution by the average ground water. The two chief sources are the decomposition of feldspars and the solution of limestone by water carrying carbonic acid in solution, which is the primary agent in rock decomposition. They are indicated in the table of analyses as alkalinity. Calcium and magnesium carbonates cause hardness in water, whereas sodium carbonate causes softness.

Bicarbonate (HCO_3). Carbon dioxide dissolved in water renders the insoluble calcium and magnesium carbonates soluble as bicarbonates. Boiling reverses the process by changing the bicarbonates into ~~insoluble~~ carbonates, which form a coating on the sides of cooking utensils.

Total Dissolved Solids (Residue on Evaporation). The term is applied to the residue obtained when a sample of water is evaporated to dryness. Waters are considered high in dissolved mineral solids when they contain more than 500 parts per million, but may be accepted for domestic use up to that point if no better supply is available. Residents, accustomed to the waters, may use waters that carry well over 1,000 parts per million of total dissolved solids without inconvenience, although persons not used to such highly mineralized waters would find them objectionable.

Hardness is a condition imparted to waters chiefly by dissolved calcium and magnesium compounds. It here refers to the soap-destroying power of water, that is, the power of the water

first to use a certain amount of soap to precipitate the above compounds before a lather is produced. The hardness of water in its original state is its total hardness. Permanent hardness remains after the water has been boiled, and is caused by mineral salts that cannot be removed from solution by boiling. It can be reduced by treating the water with natural softeners, such as ammonia or sodium carbonate, or with many manufactured softeners. Temporary hardness can be eliminated by boiling, and is due to the presence of bicarbonates of calcium and magnesium. Waters containing larger quantities of sodium carbonate than of calcium and magnesium compounds are soft, but if the latter compounds are more abundant the water is hard. The following table¹ may be used to indicate the degree of hardness of a water:

<u>Total Hardness</u>	
<u>Parts per million</u>	<u>Character</u>
0-50	Very soft
50-100	Moderately soft
100-150	Slightly hard
150-200	Moderately hard
200-300	Hard
300 and over	Very hard

¹
Thresh, J. C., and Beale, J. F.; The Examination of Waters and Water Supplies, p. 21, London, 1925.

PART II

WILLIAMSBURGH TOWNSHIP, DUNDAS COUNTY, ONTARIO

PHYSICAL FEATURES

Williamsburgh township is in the southeast part of Dundas county and has an area of approximately 99 square miles. The township extends along the northwest side of the St. Lawrence River from a point $1\frac{3}{4}$ miles west of the town of Morrisburg to $7\frac{1}{2}$ miles east of the same municipality. The town of Morrisburg, the largest community within the township, lies about 105 miles west of the city of Montreal.

The topography of the greater part of Williamsburgh township is that of ground moraine. It is rolling or undulating with no main topographic features. An area of flat-lying marine sand and clay extends south from the north boundary immediately east of Winchester Springs, to the area about the community of Williamsburg. The areal extent of this sand-clay plain, which constitutes the largest "flat" in the entire township, is approximately 10 square miles. A number of small, clay till ridges, projecting through the sand and clay, provide the only relief in the area. The general trend of the topography varies from north-south to south 10 degrees west. Bedrock, which consists of flat-lying Ordovician sedimentary formations, is exposed in a few, scattered outcrops in the north part of the township. The depth of overburden is such that except in the north part of the township, bedrock does not exert any great influence upon the topography.

A poorly marked divide between the basins of the Ottawa and St. Lawrence Rivers crosses the centre of the township in a southwesterly direction. The divide crosses Highway 19 about $1\frac{1}{4}$ miles south of the community of Williamsburg and intersects the east boundary of the township in concession VI.

Both sides of the divide are drained by numerous, small creeks whose directions of flow are controlled to a great extent by the trend of the topography. The creeks, south of the divide, empty directly into the St. Lawrence River whereas those on the north flow

into South Nation River and thence to the Ottawa. Hoasic Creek, possibly the largest in the township, empties into the St. Lawrence River 1 mile east of the town of Morrisburg. The fact that swamp deposits cover 25 per cent of the township is an indication that the surface drainage is relatively poor.

The township as a whole has a relief of more than 75 feet. It ranges from altitudes greater than 300 foot above sea-level in several localities in the northeast part of the township to less than 225 feet at the St. Lawrence River in the southeast corner.

Graphs have been prepared depicting the monthly precipitation from 1947 to the end of 1950, as measured at various meteorological stations in the area about Matilda township, and the fluctuations in the water-table as measured at an observation well near the town of Morrisburg. Data for the latter were provided through the courtesy of the Ontario Department of Mines.

From the graph, it will be noted that, during the months when the ground is not frozen, the elevations of the water-table depend, to a large extent, upon the amount of precipitation falling upon the area. In general, the lowest amount of precipitation occurs during the months of August and September, and it is during this time that the water-table shows a steady decline, reaching its lowest point commonly in the month of October.

In the subsequent months, there are periods of considerable precipitation. However, because the frozen condition of the ground prevents downward percolation of water and because much of the precipitation is in the form of snow, the water-table remains low during the winter months and does not commence to rise until the end of February.

The highest elevation of the water-table is reached during the months of May and June. This is probably due to the supplementing of the normal precipitation with water produced by the melting of the snow and ice accumulated on the surface during the winter months.

Precipitation in inches ^x

Station	Year	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
Brookville	1950	6.0	3.6	4.6	2.5	1.8	1.4	3.2	5.6	1.3	2.8	5.8	3.7	42.3
	1949	3.6	3.3	2.8	4.7	2.8	2.3	1.9	3.0	4.4	1.8	4.5	3.4	38.5
	1948	3.1	3.0	4.6	2.6	3.8	3.8	3.5	1.3	0.6	2.9	5.4	3.6	38.1
	1947	4.7	2.4	5.5	2.1	7.0	4.5	6.0	1.6	4.5	1.0	3.7	3.1	46.1
	1946	3.4	2.7	1.4	2.1	4.3	1.8	2.9	2.0	3.2	5.7	3.3	4.9	37.7
Donville	1950	3.8	3.2	3.7	2.7	2.0	1.1	4.3	4.1	-	1.8	4.5	3.1	-
	1949	2.6	3.3	2.6	5.0	2.2	1.2	2.2	3.4	3.3	1.7	3.3	3.3	34.1
	1948	-	-	-	-	2.7	2.9	3.5	2.3	0.2	2.7	4.2	2.8	-
	1947	-	-	-	-	-	-	-	-	-	-	-	-	-
	1946	-	-	-	-	-	-	-	-	-	-	-	-	-
Kemptonville	1950	3.8	3.6	3.6	3.0	1.8	1.3	3.0	3.9	1.0	1.9	4.4	2.6	33.9
	1949	5.2	3.0	2.1	4.6	2.8	0.6	2.2	4.8	3.2	1.7	3.5	2.4	34.6
	1948	1.4	2.1	3.3	2.1	2.9	3.1	3.4	2.9	0.6	2.9	4.1	3.5	32.3
	1947	3.6	1.7	5.5	1.9	4.0	3.4	7.4	2.3	5.2	0.3	2.7	1.5	39.5
	1946	2.9	1.5	1.2	2.3	3.8	1.6	2.0	1.6	2.7	5.0	3.5	3.8	31.9
Morrisburg	1950	4.5	3.7	3.8	2.8	1.3	1.8	4.9	5.1	1.4	2.0	5.9	4.4	41.6
	1949	4.2	4.0	2.6	4.2	2.6	0.8	1.9	1.9	5.0	2.0	3.7	3.1	35.0
	1948	1.6	3.3	3.8	2.4	2.8	3.5	3.1	3.6	0.1	3.0	5.1	3.6	35.9
	1947	5.3	3.0	5.9	2.1	5.6	5.8	7.7	1.6	5.8	0.6	3.7	3.1	50.1
	1946	3.0	2.0	1.8	2.6	4.6	1.6	1.5	1.5	4.5	6.4	3.8	4.3	37.6

^x Extracts from the 'Monthly Weather Map', Meteorological Service, Dominion of Canada

WATER-TABLE ELEVATIONS AT OBSERVATION WELL

Name: W. T. Richardson

Address: R.R. No. 1, Morrisburg, Ontario

Well type: dug

Well depth: 25 feet (Aug. 22, 1951)

Well elevation: 248.0 feet above sea-level

Material from which ground water derived: clay till

Year	Jan.	Feb.	March	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1947	235.4	237.2	234.9	237.4	240.1	242.8	239.0	237.9	235.7	256.1	234.9	236.8
1948	234.3		237.4	236.4	235.7	237.5	233.8		230.9	229.2	230.3	230.6
1949	230.6	230.7	250.1	235.3	237.4	255.3	233.4	231.9	230.5	230.7	230.5	239.6
1950				234.7	236.7			234.3	233.9		233.4	

PRECIPITATION IN INCHES

ELEVATIONS OF WATER TABLE

(feet above sea level)

8.0
6.0
4.0
2.0
0.0

242
240
238
236
234
232
230

Graph depicting the amount of precipitation in the Morrisburg, Ontario area from the period Jan. 1947 to Dec. 1950.

J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
1947 1948 1949 1950

Graph depicting the fluctuations in the water table in the Morrisburg, Ontario area from the period Jan. 1947 to Dec. 1950. (Courtesy of the Ont. Dept. of Mines)

GEOLOGY

Bedrock Formations

The township, which is located within the Ottawa-St. Lawrence lowland, is underlain by Palaeozoic rocks of Ordovician age. In most cases the rocks are flat-lying or gently undulating with no general direction of strike or dip.

TABLE OF FORMATIONS ¹

Era	Period	Sub-epoch	Formation	Thickness (feet)	Lithology	
Palaeozoic	Ordovician	Trenton and Black River	Ottawa	600-700	Limestone with a little shale and some sand at base	
		Disconformity				
		Chazy	St. Martin Rockcliffe	20-155 150-165	Impure limestone Shale with sand- stone lenses	
		Disconformity				
	Ordovician or Cambrian	Beckmantown	Oxford	240($\frac{1}{2}$)	Dolomite with a little shale at top	
			March	30($\frac{1}{2}$)	Interbedded sand- stone and dolomite	
			Nepoan	up to 500	Sandstone	
Great Unconformity						
Procambrrian (Archean)			Grenville		Crystalline lime- stone, quartzites, and metamorphic rocks; associated granite and granite gneiss	

¹Wilson, A.E.: Geology of the Ottawa-St. Lawrence Lowland, Ontario and Quebec; Geol. Surv., Canada, Mem. 241, p. 9 (1946).

Williamsburgh township is underlain by several formations, of which the Ottawa comes to the surface or directly underlies the drift in the entire township except for the southeast corner and extreme south part where its place is taken by the St. Martin formation. A number of small outcrops of the Ottawa formation occur in the northeast part of the township.

Unconsolidated Material

The types of unconsolidated material occurring in the township, classified according to their origin and arranged in order of their deposition from oldest to youngest, are as follows: glacial, marine, and Recent.

The glacial drift that covers approximately 86 per cent of the township occurs chiefly as ground moraine. The ground moraine, consisting mainly of clay till, is composed largely of material derived from the underlying Palaeozoic rocks and contains many boulders and rock fragments of local origin. The unweathered till varies from a bluish grey, compact, unstratified clay till to a dark brownish, looser, sandy clay till. An excellent section of clay till occurs along the east branch of Hoasic Creek about 1 mile south of the C.N.R. tracks. Here the creek has cut a 15-foot vertical face in the till disclosing boulders of limestone and crystalline rocks up to 12 inches in diameter embedded in a clayey matrix. Numerous, artificial excavations on the outskirts of the town of Morrisburg have exposed clay till at various depths. Information obtained from numerous well owners indicates that the considerable areas of swamp lands in the township are underlain by clay till. This is excellent evidence of the relative impermeability of the till. Thin layers of till reworked by the invading marine waters of the Champlain Sea, and thicker deposits of marine sand and gravel occur on the northwest flanks and tops of some of the higher ridges. They are frequently associated with accumulations of large boulders.

The invasion and subsequent withdrawal of the Champlain Sea, which followed the retreat of the ice-sheet in the region, formed a variety of deposits of marine origin. The largest of these is an area of flat-lying clay and sand extending from Winchester Springs south to the community of Williamsburg in the northwest part of the township. Smaller areas of the same materials occur throughout concessions VII and VIII. An irregular deposit of marine clay extends along the northwest bank of the St. Lawrence River from the east boundary of the township west to within 1 mile of Morrisburg.

Recent beds of fine to coarse sand, formed during earlier and higher stages of the St. Lawrence River, extend along the north-west bank of the river, in the same general area as the marine clay. The alluvium overlies much of the marine material in the area and is continuous with similar deposits to the east in adjacent Osnabruk township. They are bounded on the north by an irregular, former river bluff whose elevation is approximately 248 feet above sea-level. A number of dunes, whose material was probably derived from the alluvial sand, occur along the base of this bluff. In the vicinity of Riverside and East Williamsburg, ridges of clay till, projecting above the surrounding sand and clay, probably existed as islands when the river was at a higher elevation.

No beds of glacio-fluvial origin are known to occur in the township. In other townships located within the Ottawa-St. Lawrence Lowlands, beds of this type have been found to be located mainly in valleys between the higher clay till ridges and buried beneath a covering of marine sand, silt, and clay. The most likely location for glacio-fluvial material in Matilda township appears to be beneath the marine clay and sand occurring in the Williamsburg-Winchester Springs area.

Variations in the thickness of the drift throughout the township were determined in many localities from the data compiled from a number of wells that were reported to have encountered bedrock. The following table indicates the minimum and maximum thicknesses of drift in some of these localities.

Concession	Lot	Minimum and maximum thicknesses of drift (feet)	Concession	Lot	Minimum and maximum thicknesses of drift (feet)
		-			-
I	1	30-?	I	19	15-30
		-			-
I	4	15-99	I	22	13-30
		-			-
I	7	11-38	I	25	16-78 ^x
		-			-
I	10	17-?	I	28	12-?
		-			-
I	13	22-49	I	31	14-?
		-			-
I	16	28-41	I	34	14-70 ^x
		-			-
		-	I	37	13-32

Concession	Lot	Minimum and maximum thicknesses of drift (feet)	Concession	Lot	Minimum and maximum thicknesses of drift (feet)
II	2	17-30	IV	25	18-?
II	5	8-48	IV	28	17-60 ^x
II	8	12-?	IV	31	11-50
II	11	11-33	IV	34	12-27
II	17	13-47 ^x	IV	37	6-22
II	20	5-43			
II	23	12-26	V	2	14-33
II	26	19-71 ^x	V	5	18-?
II	29	13-45	V	11	18-?
II	32	22-?	V	14	12-28
II	35	35-?	V	23	10-25 ^x
			V	26	32-?
III	3	19-43	V	29	22-40 ^x
III	6	9-26	V	32	10-?
III	9	17-28	V	35	16-?
III	15	6-21			
III	18	15-?	VI	2	11-?
III	21	21-?	VI	5	19-35
III	24	23-?	VI	11	11-28
III	27	8-66	VI	20	10-21 ^x
III	30	18-?	VI	23	20 ^x -43 ^x
III	33	22-?	VI	26	16-33
III	36	20-?	VI	29	18-?
			VI	32	14-20 ^x
IV	1	15-30	VI	35	2 ^x -18 ^x
IV	4	14-35 ^x			
IV	7	21-?	VII	3	12-?
IV	10	20-?	VII	6	2 ^x -?
IV	13	18-36	VII	9	15-28
IV	19	27-?	VII	12	9 ^x -22 ^x
IV	22	19-28	VII	15	16-27

Concession	Lot	Minimum and maximum thicknesses of drift (feet)	Concession	Lot	Minimum and maximum thicknesses of drift (feet)
VII	18	13-53 ^x	VIII	10	10 ^x -18 ^x
VII	24	16 ^x -21 ^x	VIII	13	17-?
VII	27	22-?	VIII	16	13-30 ^x
VII	30	6 ^x -8 ^x	VIII	19	10-31
VII	33	3 ^x - 22 ^x	VIII	22	25-37
VII	36	13 ^x -15 ^x	VIII	25	9-22
			VIII	31	14 ^x -28 ^x
VIII	1	7 ^x - 18 ^x	VIII	34	6 ^x -?
VIII	4	14 ^x -16 ^x	VIII	37	17 ^x -?
VIII	7	9 ^x -11 ^x			

^x - To bedrock

WATER SUPPLY

As a whole, Williamsburgh township appears to be fairly well supplied with ground water for both domestic and stock purposes. About 82.7 per cent of the wells are of the dug type and 23.9 per cent are drilled, chiefly into bedrock. Approximately 86.5 per cent of the wells obtain their water from depths of 40 feet or less. A survey of the well records show that about 89.9 per cent of the wells have a permanent water supply, sufficient for the present demands made upon them; and the remainder constitute dry holes and wells that go dry intermittently, especially during periods of extended drought. The description of the principal beds that yield water to the wells was based chiefly on the statements of owners and drillers as to the character of the aquifer.

Although the clay till in the township is by far the most common material yielding water to producing wells, it constitutes a poor reservoir for ground-water storage as it takes up water slowly and holds relatively little. Furthermore, the quality of the ground

water is generally poor because of the slow circulation. Many shallow wells, dug in clay till, are reported to be 'intermittent' or 'low in summer'. The reason for this is the low permeability of clay till, which causes it to yield its water slowly to wells. Such wells are, consequently, easily pumped dry and take a comparatively long time to recover. In late summer when the water-table is low, the decreased area of material yielding water directly to the well renders the supply even more unsatisfactory. To overcome this difficulty, the owner should dig his well sufficiently deep to form a reservoir holding enough water to permit a large amount to be withdrawn before emptying the well.

The average depth of the different classes of wells dug in clay till in lots 22 to 37, con. I, which includes the area about the town of Morrisburg, is as follows: sufficient supply, 30.6 feet; low in summer, 26.7 feet; intermittent wells, 14.7 feet; not used, 22.4 feet. Along the road separating cons. I and II, the average depth is: sufficient supply, 36.4 feet; low in summer, 24.6 feet; intermittent wells, 19.6 feet; not used, 21.1 feet.

The water wells classified as having "sufficient supply" are those that are reported to yield "satisfactory" supplies of ground water during the entire year. "Intermittent wells" are those that go dry during some period of the year, but wells described as "low in summer" do not go entirely dry, although the water level recedes to a point during the late summer to early autumn where it is not possible to obtain a large supply of water. Wells that are "not in use" are included because it was found that the chief reason for their not being used was that they could not supply satisfactory quantities of water when it was required.

It will be noted that the figures for the average depths range from a maximum for those wells with "sufficient supply", to a minimum for those with an "intermittent supply". The average depth of wells "not in use" is usually, but not always, found between those classified as "low in summer" and "intermittent".

These relationships are found to be consistent throughout the township. In any one locality, the depths of the individual wells of each of the above mentioned classes depend upon the depths to the water-table and, as the depth to the water-table varies considerably across the township, the average depth of the wells varies in accordance.

The comparative figures mentioned above indicate the necessity of deepening wells in clay till that do not provide sufficient quantities of ground water during the entire year. Wells that are intermittent would have to be deepened more than those classified as "low in summer". It is suggested to farmers or other persons planning to dig a well in clay till that the well be dug during the late summer or early autumn when the water-table is normally at its lowest point. If a sufficient supply of water can be obtained at this time, it is reasonable to assume that the well will yield a satisfactory supply of water during the entire year. The following figures should also be considered; a well 4 feet in diameter holds 78.3 gallons of water per foot of depth, and a well 3 feet in diameter holds 44.1 gallons per foot. Before digging the well the prospective owner should make a fairly accurate estimate of the amount of water required and construct it accordingly.

It was reported that a number of wells dug to various depths in clay till encountered a "spring" in the bottom of the well. The water was not under hydrostatic pressure, although it flowed freely into the well during pumping operations. It is doubtful if the material yielding water at the bottom of these wells is clay till, but more probably consists of a lens or pocket of sand or gravel, many of which are reported to be scattered throughout the till. The quantity of water yielded by these more porous materials depends upon the extent of the aquifer. It is believed that the most of these sand and gravel lenses draw their water from the confining till, and, consequently, the chief result of their presence is to cause a greater area of till to yield its water to the well. Some of these wells yielded large quantities of water when first dug, but after a period

of time, assumed the properties of wells deriving their entire water supply of ground water from clay till, often going dry during the late summer or extended periods of drought and yielding only limited supplies during normal times. In lots 18 to 20, con. II, it was authentically reported that 6 non-artesian wells, all dug into clay till, are obtaining their water from gravel located within the till. The depths of these particular wells range from 5 to 43 feet with an average depth of 20 feet.

Ground water under hydrostatic pressure is seldom yielded by clay till. In most instances, the wells are non-artesian and are deriving their water from the zone of saturation below the water-table. A possible exception is one of two wells dug to the same depth in clay till, 100 feet apart and at approximately the same elevation, located in lot 19, con. V. The level of the surface of the water in one well is 6 feet higher than that in the other. It is possible, in this case, that the well in which the water stands higher is non-flowing artesian, that is, the ground water encountered by the well was under some hydrostatic pressure.

Sufficient supplies of ground water, some of which is under pressure, are frequently obtained at the contact of clay till and the underlying bedrock. For wells such as these, the aquifer has been described on the compilation sheets as, "contact, till-bedrock". It is thought, however, that, although most of the ground water enters the well at the contact, some water enters from the till higher up in the well. Much of the till lying immediately above bedrock is saturated with water. This does not necessarily imply that, at that point, the true water-table is in the till. It may be at a considerable depth below in the bedrock, and the water in the till may be perched, its slow percolation downward through the till being even more retarded by the presence of bedrock. This is suggested by the fact that the till appears to be saturated with water only immediately above bedrock that is massive and where there are few cracks or joint planes to carry the ground water farther downward into the rock. Several wells of this type are located in lots 19 to 27, con. VIII, in the vicinity of the

community of Dunbar. The depths of the wells depend upon the depth to bedrock at each particular location. These wells are all reported to be satisfactory and to be yielding sufficient quantities of ground water.

A number of wells dug into the marine sand and clay deposits occurring in the Williamsburg-Winchester Springs area have encountered what is locally called a "water gravel" lying beneath the clay. Although no flowing-artesian wells were reported, the water contained in these "water gravels" is under sufficient hydrostatic pressure to force it up considerable distances in the wells. It is thought that these porous gravel beds consist of outwash material and are similar to those encountered beneath the marine sediments approximately 8 miles west in the vicinity of the community of Hulbert, Matilda township. These beds could possibly be developed into an important local source of ground water.

The following is the log of a well dug in lot 25, con. VIII, which encountered "water gravel" beneath marine clay.

0 to 10 feet	-	marine clay
10 to 11 "	-	hard, compact sand
11 to 14 "	-	quicksand
14 to 22 "	-	"water gravel"

It was reported in this particular well that the water was under considerable pressure and that continual pumping could not lower the water level in the well below 10 feet from surface.

The marine clay beds that are scattered throughout the township yield various quantities of water to wells, 63 of which are non-artesian and the remaining 8 intermittent. The problems encountered in attempting to obtain satisfactory supplies of ground water from marine clay are comparable with those in clay till areas. Marine clay is too dense to yield its water content readily, and wells dug in this material necessarily have to go a considerable distance below the water-table in order to provide a reservoir large enough to yield a satisfactory supply of water. Most wells dug in marine clay that

are reported to be unsatisfactory are so not because of the lowering of the water-table but because of the low permeability of the material. Owing to this poor permeability, most wells could be dug in clay a considerable distance below the water-table before there would be any free water in the well. It is suggested that the only accurate method to locate water-table in clay is to test the material for saturation in the laboratory. A well dug in clay would necessarily have to remain in disuse for a considerable length of time before the elevation of the surface of the free water would approach that of the water-table.

The largest and most important areas of marine clay in Williamsburgh township are in concessions I and VIII. Altogether, 49 dug wells in concession I are reported to obtain their water from marine clay. These wells vary in depth from 9 to 41 feet with an average depth of 22.2 feet. One group of 16 wells in lots 14 to 17 has an average depth of 26.5 feet. All wells in clay in concession I have been classified as non-artesian with the exception of 7 intermittent. The depths of the intermittent wells range from 10 to 37 feet, indicating that there is no depth in the marine clay below which water may be obtained with certainty. There are 11 dug wells in concession VIII that are obtaining their supply of ground water from marine clay. These wells, which are much shallower than those in concession I, vary in depth from 9 to 19 feet with an average of only 14.7 feet. The 9-foot well is the only intermittent one in the concession, the remainder being classified as non-artesian. It is thought that deepening any intermittent well in the township deriving its water from marine clay would make it more satisfactory.

Exclusive of the community of Williamsburg only 9 wells are reported to be deriving their supply of ground water from the area of marine sand extending north from this community to Winchester Springs. The depths of these wells vary from 8 to 28 feet, with an average depth of 16.1 feet. The depths of wells deriving their ground-water supplies from sand farther south in concessions I and II are much greater. Here the wells range from 11 to 54 feet in depth, with an

average of 28.6 feet.

Precipitation falling upon these sandy areas sinks in rapidly and percolates downward until it reaches the more impervious marine clay. The clay slows the downward percolation of the water to such an extent that the sand immediately above frequently becomes saturated with water to form a perched water-table. A few wells dug down through the sand are reported to have encountered "quicksand" or "springs" in the bottom of the well. This is merely sand saturated with ground water lying above the marine clay. It is difficult to determine if the water in wells dug through sand into the underlying clay is perched or not, because the great permeability of the sand permits surface water to pass through it and fill the well rapidly to the level of the perched water-table. It is probable that the water in shallow wells, 15 feet or less in depth and dug in marine sand overlying clay, is perched, and that yielded by the deeper wells dug in the same material is from below the true water-table. Shallow wells, depending upon perched water, will go dry more readily and are more likely to be intermittent than deep wells in the same locality. The thickness of the saturated part of the sand immediately overlying marine clay is, in most places, from 1 foot to 3 feet. Most wells of this type are dug down through the sand until either the clay is encountered or the sand becomes so fluid as to render further deepening of the well extremely difficult. The depth of such a well is a good indication of the thickness of the sand at that point.

A few "sand-point" wells, formed by driving casing chiefly 2 inches in diameter into the sand, are found in the area about the community of Williamsburg. Although the small reservoir of water in the pipe allows wells such as these to be pumped dry rapidly, the high permeability of the sand permits them to refill quickly. Most owners claim that they are satisfactory for domestic use but not for watering any large number of stock, which would indicate that they are not capable of yielding large quantities of ground water over relatively short periods of time.

Altogether, some 160 wells have been drilled into bedrock in the township, and all are reported to be deriving at least part of their ground water from that source. The depths of such wells range from 11 to 275 feet with an average of 107.9 feet.

A compilation of data from wells reported drilled to bedrock in Williamsburgh township, arranged according to the formation from which the water is considered to be derived, is as follows:

Formation	Number of wells	CLASSIFICATION				DEPTHS OF WELLS (feet)			DEPTH TO WATER (feet)			QUALITY			
		F.A.	N.F.A.	N.L.	I.N.	Min.	Max.	Ave.	Min.	Max.	Ave.	Hard	Soft	Sal-ine	Sul-phur
Ottawa	148	0	30	113	5	87	176	118.2	3	30	12	139	2	1	6
St.Martin	12	1	8	3	0	11	275	63.9	2	33	12.7	11	0	0	1
TOTAL	160	1	38	116	5							150	2	1	7

The above figures do not take into consideration wells drilled into bedrock within the communities of Mariatown and Williamsburgh. One well was drilled in the latter to a depth of 365 feet.

The St. Martin formation, consisting of limestone, minor shale, and dolomite, underlies the southwest and extreme south parts of Williamsburgh township. Along Kings Highway No. 2, between lots 7 to 15, con. I, it was encountered at depths from 50 to 60 feet, and in lot 25, con. I, midway between Riverside and Morrisburg, at 78 feet from the surface.

Although the St. Martin formation underlies approximately 20 per cent of Williamsburgh township, it is the source of ground water for only 7.5 per cent of the wells drilled to bedrock. From the information compiled, however, the St. Martin would appear to be an excellent source of ground water. Approximately 75 per cent of the wells penetrating the St. Martin encountered water under sufficient hydrostatic pressure to force it a considerable distance up into the well. A flowing artesian well, drilled to a depth of 119 feet in lot 14, con. I, is thought to be deriving its supply of ground water from this source. The piezometric surface of the water at this point is

approximately 6 feet above the surface of the ground, and, on September 13, 1951, the rate of flow of the well was 36 gallons an hour. The temperature of the water was 42° F. The ground water obtained from the St. Martin is reported to be very hard; only one well, located in lot 5, con. I, was observed to have a strong hydrogen sulphide odour.

The Ottawa formation, which consists of grey limestone with dolomite, shale, and sandstone in the lower part, underlies 80 per cent of the township. Because of the relatively thin layer of drift covering bedrock in the north part of Williamsburgh township, 69 per cent of the wells in the township drilled into this formation are located in concessions VI, VII and VIII. This is especially true in the northwest and northeast corners of the township where the nearness of the flat-lying bedrock to surface is reflected in the extremely flat topography.

The quantity of ground water yielded to the individual wells by the Ottawa formation is not as large as from the underlying St. Martin. In some localities it appears to be a matter of chance if an aquifer yielding a sufficient supply is encountered by drilling. In lot 35, con. VI, for instance, two wells that are intermittent have been drilled into the Ottawa formation to depths of 95 and 100 feet, and in lot 36 in the same concession, wells drilled 30 and 100 feet, also into the Ottawa, have been described as highly satisfactory. Similar conditions have been encountered in other parts of Williamsburgh township. It is reported by well drillers that, except for the top few feet, the Ottawa formation is massive with a few joint or bedding planes sufficiently open to form good aquifers. A few wells, however, have been reported to be obtaining large quantities of ground water from the Ottawa. A well, drilled 23 feet, at the cheese factory in Dunbar, concession VIII, for instance, will produce from 175 to 250 gallons an hour, and a well in lot 3, con. VIII, drilled 100 feet into the Ottawa is reported to yield 900 gallons an hour.

Altogether, some 148 wells are reported to be drawing their supply of ground water from the Ottawa formation, of these, 30 (20.3 per cent) are non-flowing artesian, 5 (3.4 per cent) are intermittent, and the remaining 113 (76.3 per cent) are non-artesian. These percentages compare closely with those of wells in adjacent Matilda township also considered to obtain their ground water from the Ottawa.

The small proportion of wells encountering water under pressure in the Ottawa formation as compared with those in the St. Martin is thought to be due, in part, to the absence of shaly members in the former. Ground water encountered beneath shale, which is relatively impervious to its passage, is often under considerable hydrostatic pressure.

A number of wells believed to derive their supply of ground water from the Ottawa formation have been reported as containing 'sulphur'. In most instances, this means that the water has a strong odour of hydrogen sulphide gas. At least three of these wells have been reported as non-flowing artesian. In adjacent Matilda township, all ground water containing hydrogen sulphide gas was thought to be coming from either the St. Martin or Rockcliffe formations and not from the Ottawa. Accordingly, it is possible that some of the sulphur contaminated ground water in Williamsburgh township may in fact be coming from the underlying St. Martin formation rather than from the Ottawa as reported.

The figures for the depths to bedrock, obtained from the drillers and owners of many water wells, indicate a gradual decrease in the elevation of the bedrock surface from east to west across Williamsburgh township. No buried channels or valleys, such as were encountered in adjacent Matilda township, appear to exist in the surface of the bedrock underlying the township.

COMMUNITY SUPPLIES

Detailed studies were made of ground water conditions in the communities of Mariatown and Williamsburg. Maps showing the location of all wells for which information has been obtained, topographic contours for both communities, and water-table contours for Williamsburg accompany this report. Although the contours are somewhat generalized they are believed to be sufficiently accurate for the purpose for which they are being used. To determine the depth to water in any one place, it is necessary only to subtract the elevation of the nearest water-table contour from that of the nearest surface contour. Compilation sheets containing pertinent data concerning the individual wells in each community are included at the back of this report.

Community of Mariatown. Although this community is situated on the bank of the St. Lawrence River, its water supply is derived entirely from privately owned, dug wells. The depths of these wells vary from 16 to 40 feet with an average of 24.6 feet, and in all instances the aquifer was reported to be clay till. Bedrock, which probably lies between 50 and 65 feet below the surface of the ground, was not encountered in any well.

With the exception of 2 wells, the quantity of water yielded by the wells in Mariatown is thought to be sufficient for domestic purposes, but not for watering a large number of stock. It is reported that most wells can be pumped dry quite easily and take a long time to recover. This is characteristic of wells deriving their entire water supply directly from till.

The depth to water was measured in 23 wells. It was found that the variations in the elevation of the water levels in the individual wells was so great that it was not possible to contour the water-table. This extreme variation is probably because some of the wells had recently been pumped and were in the process of slowly recovering to the level of the water-table.

Sufficient ground water for the purpose of fire fighting can probably not be obtained from any dug well within the community. The proximity of the St. Lawrence River, however, makes Mariatown much more fortunate than most small communities in the quantity of water available for this purpose.

Community of Williamsburg. The water supply of the community of Williamsburg is derived entirely from privately owned wells. Altogether, there are 86 wells supplying ground water to the inhabitants of the community. Of these, 40 are dug and 24 are drilled, chiefly into the underlying Ottawa formation, and 21 consist of sand points driven to various depths into the marine sand that constitutes the surface material in the south and west parts of the community. No information was obtained regarding the remaining well.

The following table is a compilation of the wells within the community arranged according to the material or formation from which they derive their supply of ground water. Two wells for which there is insufficient information have not been included.

Material or Formation	Number of wells	CLASSIFICATION				DEPTHS OF WELLS (feet)			DEPTH TO WATER (feet)			QUALITY			
		F.M.	N.F.M.	N.M.	I.M.	Min.	Max.	Ave.	Min.	Max.	Ave.	Hard	Soft	Sal- ine	Sul- phur
Sand	18	0	0	17	0	4	48	18.9	2	9	4.6	18	0	0	0
Clay	10	0	0	9	1	12	20	14.7	4	10	7.6	10	0	0	1
Clay till	33	0	0	25	9	11	45	18.4	4	15	7.9	32	1	0	0
Gravel	3	0	1	1	1	12	80	35.0	6	12	9.0	3	0	0	0
Ottawa															
Limestone	20	0	19	1	0	85	365	123.7	5	20	8.8	19	1	1	9
TOTAL	84	0	20	53	11							82	2	1	10

The wells put down into sand, clay, or clay till all derive their supply of ground water from the zone of saturation below the water-table, and are accordingly classified as non-artesian. A number of these wells were reported as intermittent, but it is thought that they would yield satisfactory quantities of ground water if deepened.

Most sand points used to obtain water from the marine sand within the community consist of a casing 2 inches in diameter. Most of these wells yield enough water to satisfy the needs of the average home, and in two cases the supply was reported to be sufficient for the operation of a restaurant. The fact that none of these sand-point wells is intermittent indicates that the sand is exceedingly permeable and yields its water readily. It also suggests that the sand points have been driven sufficiently far below the lowest elevations to which the water-table will drop during its seasonal fluctuations to assure a permanent supply of ground water.

The Ottawa formation, which directly underlies the unconsolidated materials within the community, is considered to be an excellent source of ground water. A well drilled to a total depth of 129 feet, 69 feet of which is in bedrock, was reported to yield sufficient water to satisfy the demands of two houses, both equipped with pressure systems attached directly to the one well. A second well, located at the hotel, was drilled to a depth of 365 feet. This particular well, which is one of the deepest in the township, was reported to yield up to 4,000 gallons a day without lowering the level of the water in the well.

A large percentage of the water in the community, derived from the Ottawa formation, has a slightly saline taste and emits a faint odour of hydrogen sulphide gas. Residents accustomed to these waters use them without inconvenience, although persons not used to such waters would probably find them objectionable.

Depth to bedrock was obtained for only 5 wells within the community, insufficient information on which to attempt to describe the surface of bedrock.

ANALYSES OF WATER SAMPLES

Ten samples of well waters from Williamsburgh township were analysed for their mineral content in the laboratory of the Mines Branch, Department of Mines and Technical Surveys, Ottawa. The samples were taken from wells from 17 to 119 feet deep with aquifers in both drift and bedrock.

The nitrate and chloride content of a large number of wells sampled appear to be abnormally high, indicating the possibility of contamination. It is suggested, therefore, that bacteriological test be made of these waters if they are to be used for domestic purposes. Most contamination of well waters results from surface water seeping into the well, either at the surface or at the bottom of the cribbing or casing. This is chiefly due to poor well construction.

¹
Amounts of Dissolved Mineral Matter
in Well Waters collected in Matilda township

Constituent	Well waters from glacial drift and bedrock (10 samples)		
	Maximum	Average	Minimum
Residue on evaporation (105°C.)	1321.0	707.8	332.0
Calcium	140.0	90.3	47.0
Magnesium	106.2	37.5	16.8
Sodium	276.0	74.7	6.4
Potassium	266.0	59.8	1.5
Sulphate	256.8	134.1	60.9
Chloride	256.8	35.9	6.0
Nitrate	165.9	58.5	0.0
Bicarbonate	734.4	339.7	231.8
Carbonate	7.2	0.7	0.0
Silica (Col.)	16.9	12.6	6.8
Total hardness	646.6	372.4	227.2

¹In parts per million.

In answer to the requests of a number of well owners, the following method is recommended when it is desired to sterilize a well : ²

²Well Drilling, Technical Manual, T.M. 5-295, United States Government Printing Office, Washington, 1943.

mix one heaping tablespoonful of chlorinated lime with a little water to make a thin paste, being sure to break up all lumps; stir this paste into 1 quart of water; allow the mixture to stand and then pour off the clear liquid. The chlorine strength of the solution is about 1 per cent; 1 quart of the liquid is enough to sterilize 800 imperial gallons of water.

Estimate the volume of water in gallons standing in the well, and for each 800 imperial gallons, pour 1 quart of the sterilizing solution into the well. No harm is done if too much solution is used, and it is better to use too much than too little. Agitate the water thoroughly and let it stand for several hours, preferably over night. Then flush the well thoroughly to remove all the sterilizing agent. The sides of the well above the surface of the water can be sterilized by returning the water to the well during the first part of the flushing. Just before completion of the flushing, a sample of the water may be taken if required.

To determine the amount of chlorinated lime solution that should be added to the well waters, it is necessary to know the diameter of the well and the depth of water in the well. With this knowledge, together with the information given in the table below, the volume of water present in the well can be easily calculated and the correct amount of lime solution added.

Diameter of well (foot)	Number of imperial gallons per foot depth
2.0	19.6
2.5	30.6
3.0	42.1
3.5	59.9
4.0	78.5
4.5	99.1
5.0	132.5

CONCLUSIONS

This investigation warrants the following conclusions:

1. Ground-water resources in Williamsburgh township, although not abundant, are adequate for domestic, stock, and community purposes.
2. Clay till is not considered a good source for ground water. However many wells dug in this material encounter layers or pockets of sand or gravel that may yield considerable quantities of water.
3. Clay constitutes the most unsatisfactory source of ground water of all the unconsolidated materials in Williamsburgh township, and wells dug in clay may go a considerable distance below the water-table before there is evidence of free water in the well.
4. Wells dug in clay and clay till that are reported as 'low in summer' or 'intermittent' would yield larger quantities of ground water if deepened. The deepening process should take place in the late summer or early autumn, when the water-table is normally at its lowest point.
5. Throughout the township, wells in sand are commonly dug down to the top of the underlying clay. Shallow wells, dug to a maximum depth of 15 feet in sand, are probably deriving their water from a perched water-table. Such wells are commonly classed as 'low in summer' or 'intermittent'.
6. The quantity and quality of the ground water yielded by the bedrock formations directly underlying Williamsburgh township appear to be satisfactory for normal domestic and farm use.
7. The quantity of ground water yielded by the clay till in the area about the community of Mariatown is sufficient for domestic but not for farm purposes.
8. The most satisfactory sources of ground water within the community of Williamsburg is the marine sand, which is chiefly located in the south part of the community, and the underlying Ottawa limestone, which constitutes the bedrock formation directly underlying the community.

Summary of Wells and Springs used as a source of Water Supply, exclusive of Communities

[illegible]

Williamsburgh Township

Summary of Wells and Springs used as a Source of Water Supply (Communities)

Wells and springs	Communities		Total number in communities	Per cent of total
	Mariatown	Williamsburg		
Total number			111	
Dug	25	86	65	58.6
Bored	25	40	0	0.0
Drilled	0	0	21	21.6
Driven	0	21	21	18.9
Wells: 0-20 feet deep				
21 - 40	10	42	52	46.8
41 - 60	15	14	29	26.1
61 - 80	0	3	3	2.7
81 - 100	0	1	1	0.9
Over - 100	0	5	5	4.5
Depth unknown	0	12	12	10.8
		9	9	8.1
Wells that yield hard water				
soft water	25	81	109	98.2
salty water	0	2	2	1.8
sulphur water	0	1	1	0.9
	0	7	7	6.3
Wells with aquifer in clay				
in sand	0	10	10	9.1
in gravel	0	18	18	16.2
in clay till	0	3	3	2.7
in bedrock	25	33	58	52.2
unknown	0	20	20	18.1
	0	2	2	1.8
Well types:				
Flowing artesian	0	0	0	0.0
Non-flowing artesian	0	19	19	17.1
Non-artesian	23	54	77	69.4
Intermittent	2	10	12	10.8
Dry holes	0	0	0	0.0
Not used	0	6	6	5.4
Spring	0	0	0	0.0

ANALYSES OF WELL WATERS FROM WILLIAMSBURG TOWNSHIP, DUNDAS COUNTY, ONTARIO

Sample number	Owner	Lot	Concession	Depth of well	Aquifer	Residue on evaporation (pts. per million)	Constituents as analysed (parts per million)										Hardness as CaCO ₃ (parts per million)			
							Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Sulphate (SO ₄)	Chloride (Cl)	Nitrate (NO ₃)	Bicarbonate HCO ₃	Carbonate CO ₃	Silica Col. (Si O ₂)	Ca hardness	Mg hardness	Total hardness	
1	G. Baker	7	I	53	C.T.	586.0	87.0	39.6	38.0	9.1	242.4	18.5	3.2	268.4	0	9.2	217.1	165.0	382.1	
2	A. G. Perley	14	I	119	St.M.	966.0	47.0	26.7	276.0	2.7	256.8	243.5	0.0	231.8	7.2	6.8	117.3	109.9	227.2	
3	Tweedie	26	I	87	St.M.	350.0	67.0	30.2	12.3	1.7	60.9	6.0	0.0	292.8	0	12.8	157.2	124.5	291.5	
4	E. Barkley	25	V	17	C.T.	508.0	112.2	22.3	38.0	13.2	124.7	40.5	31.9	356.2	0	8.4	279.9	91.8	371.7	
5	P. Lecko	26	V	32	G.	332.0	89.0	16.8	30.0	33.5	74.9	25.0	127.6	259.6	0	12.8	222.1	69.1	291.2	
6	C. Hess	30	VI	90	Ott.	458.0	101.0	53.4	6.4	1.5	73.2	15.5	1.6	378.2	0	15.6	252.0	137.4	389.4	
7	H. Berkley	35	VI	100	Ott	1172.0	140.0	40.6	26.0	266.0	86.3	256.3	113.4	624.6	0	16.9	349.3	167.1	516.4	
8	R. Berkley	19	VIII	31	C.T.	536.0	99.0	28.0	46.0	35.5	67.9	36.5	56.7	451.4	0	16.0	247.0	115.2	362.2	
9	C.F. Marcellus	21	VIII	75	Ott.	1324.0	93.0	106.2	43.2	160.0	252.7	29.5	85.1	734.4	0	15.6	209.6	437.0	646.6	
10	W.M. Marcellus	22	VIII	25	C.T.-Ott.	842.0	77.0	31.0	131.0	75.0	100.4	87.5	165.9	419.7	0	11.6	192.1	127.6	319.7	

C.T. - Clay till Ott - Ottawa

G. - Gravel Ox. - Oxford

St.M. - St. Martin

ABBREVIATIONS

The following is a list of abbreviations used in the included water well compilation sheets for the communities of Mariatown and Williamsburg.

Type, column 4

D. = dug
Drl. = drilled
Spt. = sandpoint

Depth to water surface, column 7

M. = measured

Aquifer, column 9

-
C. = clay
C.T. = clay till
G. = gravel
S. = sand
Ot. = Ottawa formation

Quality, column 11

-
C. = clear
H. = hard
S. = soft
Sal. = saline
Sul. = sulphurous

Use, column 12

-
D. = domestic
N. = not used
S. = stock

Community of Williamsburg, Williamsburgh township, Dundas county, Ontario

Well No.	Con.	Lot	Type	Altitude in feet above sea- level	Depth (feet)	Depth to water surface (feet) (Sept. 1950)	Depth to bedrock (feet)	Aquifer	Yield (gals. per hour) (approx.)	Quality	Use	Remarks
1	2	3	4	5	6	7	8	9	10	11	13	13
1	V	30	D.	260	11	7M		C.T.		H.C.	D.	Goos dry during late summer.
2	V	30	Spt.	266	15	3		S.		H.C.	D.	Sufficient; at house.
3	V	30	Spt.	266	15	3M		S.		H.C.	N.	
4	V	30	Drl.	266	202	6M	75	ot.		S.Sal.	D.	Sufficient for three families
5	V	30	D.	264	15	2M	75	S.		H.C.	N.	
6	V	31	Spt.	266	21	4		S.		H.C.	D.	Sufficient; at house.
7	V	30	D.	276	21	13M	40	C.T.		H.C.	D.	"
8	V	30	Drl.	268	100	7M	100	ot.		H.C.	D.	"
9	V	31	Drl.	268	200	12		ot.		H.C.	D.	Sufficient; at house.
10	V	30	Spt.	278	41	12		C.T.		H.C.	D.	Goos dry during late summer.
11	V	30	D.	263	12	7		C.T.		H.C.	D.	Sufficient.
12	V	31	D.	266	11	4M		C.T.		H.C.	D.	"
13	V	30	Drl.	274	83	1M		ot.		H.Sal.	D.	Goos dry during late summer.
14	V	30	D.	272	12	9M		G.		H.C.	D.	Sufficient; at house.
15	V	30	Spt.	266	4	2M		S.		H.C.	N.	
16	V	31	D.	266				S.		H.C.	D.	Sufficient.
17	V	31	Spt.	266				S.		H.C.	D.	Sufficient; at house.
18	V	32	Drl.	264	35	6M		ot.	10 +	H.C.	D.S.	
19	V	32	D.	263	13			C.T.		H.C.	D.	"
20	V	32	Drl.	266	12			C.		H.C.	D.	Goos dry during late summer.
21	V	30	D.	270	14	6M		C.T.		H.C.	D.	Goos dry during late summer.
22	V	31	D.	264	14	7M		C.		H.C.	D.	Sufficient.
23	V	30	D.	276	34	16M		C.T.		H.C.	D.	"
24	V	31	D.	266	15	10M	60	C.		H.C.	D.	"
25	V	31	Drl.	266	125	12		ot.	20 +	H.C.	D.	"
26	V	30	Spt.	270	24	5		C.T.		H.C.	D.	"

(Williamsburgh Cent'l)

1	2	3	4	5	6	7	8	9	10	11	12	13
27	V	31	Spt.	266	14	8		C.T.		H.C.	D	Sufficient.
28	V	31	D.	266	365	5M		C.	165	H.C.	D.	"
29	V	31	Drl.	266	17	10M		Ot.		H.Sul.	D.	Sufficient for hotel
30	V	31	D.	266	14	7		C.T.		H.C.	D.	Sufficient
31	V	31	D.	266	20			C.		H.C.	D.	"
32	V	31	Spt.	266	24	4		C.		H.C.	D.	" ; at garage
33	V	30	Spt.	266	11	7M		S.		H.C.	D.	"
34	V	30	D.	266	13	4M		S.		H.C.	D.	"
35	V	31	D.	264	17	9M		C.		H.Sul.	D.	"
36	V	30	D.	268	12			C.T.		H.C.	D.	"
37	V	30	Drl.	268	12	6M		Ot.		H.Sul.	D.	"
38	V	31	D.	264	90	10		C.		H.C.	D.	"
39	V	30	Drl.	278	17			Ot.		H.C.	D.	"
40	V	31	D.	268	14	8M		C.T.		H.C.	D.	"
41	V	31	D.	266	14			S.		H.C.	D.	"
42	V	31	D.	266	14	7M		C.T.		H.C.	D.	"
43	V	30	Drl.	272	160			Ot.	20 +	H.C.	D.	" for two families
44	V	30	Drl.	268	110	5M		Ot.		H.Sul.	N.	"
45	V	31	Drl.	266	132	5	65	Ot.		H.C.	D.	"
46	V	30	Drl.	270						H.C.	D.	"
47	V	31	Spt.	266	22	4		S.		H.C.	D.	"
48	V	30	D.	270	12	7M		C.T.		H.C.	D.	Goos dry during summer.
49	V	31	D.	266	9	3M		S.		H.C.	D.	Sufficient; at house.
50	V	31	Drl.	270	148	17	97	Ot.		H.Sul.	D.	" at garage.
51	V	31	D.	270	12	7M		C.T.		H.C.	S.	Sufficient
52	V	30	Spt.	268	20	7		C.T.		H.C.	D.	"
53	V	31	Drl.	270	80	12		G.	30 +	H.C.	D.	"
54	V	31	D.	266	16	6M		C.T.		H.C.	D.	"
55	V	30	Spt.	266	19	4		S.		H.C.	D.	"
56	V	30	D.	272	11	8M		C.T.		H.C.	D.	Goos dry during late summer.
57	V	31	D.	268	13	8M		C.T.		H.C.	D.	" " "
58	V	30	D.	274	13	6M		G.		H.C.	D.	Sufficient.
59	V	30	Spt.	266	27	5		C.T.		H.C.	D.	Sufficient.

(Callinurus Cont'd)

1	2	3	4	5	6	7	8	9	10	11	12	13
60	V	30	Spt.	266	22	4		S.		H.C.	D.	Sufficient; at house.
61	V	31	Spt.	266	27	4		S.		H.C.	D.	" at garage.
62	V	30	Spt.	266	45	8M		C.T.		H.C.	D.	"
63	V	30	Spt.	266	25	5		C.T.		H.C.	D.	"
64	V	30	D.	272	15	10M		C.T.		H.C.	D.	"
65	V	30	Drl.	274	98	6		Ob.		H.Sul.	D.	"
66	V	30	Drl.	272	114	6M		Ob.		H.Sul.	D.	Flows during spring.
67	V	30	Drl.	270	110	6		Ob.		H.Sul.	D.	Sufficient.
68	V	30	D.	270	13	7		C.T.		H.C.	D.	Too dry during summer.
69	V	30	D.	263	11	6M		C.T.		H.C.	D.	" "
70	V	31	D.	266	12	6M		Ob.		H.C.	D.	"
71	V	30	Drl.	263	27			C.T.		H.C.	D.	Sufficient.
72	V	30	Spt.	266	13			C.T.		H.C.	D.	"
73	V	31	D.	266	13	6M		C.T.		H.C.	D.	"
74	V	31	D.	263	25	10		C.T.		S.C.	D.	"
75	V	29	Drl.	282	173	6		Ob.		H.Sul.	D.	"
76	V	30	Drl.	263	15			Ob.		H.C.	D.	"
77	V	31	L.	266	15	10M		C.		H.C.	D.	"
78	V	30	D.	263	15	8M		C.T.	15 +	H.C.	D.	Sufficient for three families
79	V	30	Drl.	274	169	20		Ob.		H.C.	D.	"
80	V	30		263						H.C.	D.	"
81	V	30	Spt.	266	22	4		S.		H.C.	D.	"
82	V	31	D.	263	12	7		C.T.		H.C.	D.	"
83	V	31	L.	272	21	15M		C.T.		H.C.	N.	"
84	V	31	Spt.	266	15	4		S.		H.C.	D.	"
85	V	31	D.	264	15	9M		C.		H.C.	D.	"
86	V	31	Drl.	263	43	3M		S.	15 +	H.C.	D.S.	"

Community of Mariatown, Williamsburgh township, Dundas county, Ontario

Well No.	Con.	Lot	Type	Altitude in feet above sea-level	Depth (feet)	Depth to water surface (feet) (Sept. 1950)	Depth to bedrock (feet)	Aquifer	Yield (gals. per hour) (approx.)	Quality	Use	Remarks
1	2	3	4	5	6	7	8	9	10	11	12	13
1	I	36	D	254	17	12M		C.T.		H.C.	D.	Sufficient.
2	I	36	D	249	25	17M		C.T.		H.C.	D.	"
3	I	36	D	260	33	15M		C.T.		H.C.	D.	"
4	I	36	D	253	31	15M		C.T.		H.C.	D.	"
5	I	37	D	249	40	26M		C.T.		H.C.	D.	Sufficient for tourist camp.
6	I	37	D	243	32	24M		C.T.	19 +	H.C.	S.	Sufficient; at barn.
7	I	37	D	259	16	9M		C.T.		H.C.	D.	Sufficient.
8	I	36	D	256	23	14M		C.T.		H.C.	D.	"
9	I	37	D	242	20	15M		C.T.		H.C.	D.	Sufficient for tourist home and cabins.
10	I	36	D	260	30	14M		C.T.		H.C.	D.	Sufficient.
11	I	36	D	260	22	15M		C.T.		H.C.	D.	"
12	I	37	D	251	20	13M		C.T.		H.C.	D.	"
13	I	37	D	252	26	13M		C.T.		H.C.	D.	"
14	I	36	D	260	33	15M		C.T.	10 +	H.C.	D.S.	"
15	I	36	D	253	16			C.T.		H.C.	D.	"
16	I	36	D	256	13	14M		C.T.		H.C.	D.	" ; at house.
17	I	36	D	254	19	9M		C.T.	6 +	H.C.	S.	Sufficient; at barn.
18	I	36	D	253	34	22M		C.T.		H.C.	D.	Sufficient.
19	I	36	D	257	13			C.T.		H.C.	D.	Dry when examined.
20	I	37	D	252	20	14M		C.T.		H.C.	D.	Sufficient.
21	I	37	D	249	22	15M		C.T.		H.C.	D.	"
22	I	37	D	246	23	9M		C.T.		H.C.	D.	"
23	I	37	D	246	27	23M		C.T.		H.C.	D.	"
24	I	36	D	257	17	14M		C.T.		H.C.	D.	"
25	I	36	D	251	27	20M		C.T.		H.C.	D.S.	"

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CANADA
DEPARTMENT OF MINES
AND
TECHNICAL SURVEYS

GEOLOGICAL SURVEY OF CANADA

WATER SUPPLY PAPER No. 319

I.

GROUND-WATER RESOURCES
OF
TOWNSHIPS 11 to 14, RANGES 26 to 29,
WEST OF PRINCIPAL MERIDIAN
MANITOBA
(Elkhorne Area)

By
E. C. Halstead



DEPARTMENT OF GEOLOGICAL SCIENCES,
UNIVERSITY OF TORONTO

OTTAWA

1953

CANADA

NOTE:

Because of difficulties involved in reproduction, the tables of well records referred to are not included with this report. Information regarding individual wells may be obtained by writing to the Director, Geological Survey of Canada, Ottawa.

CANADA
DEPARTMENT OF MINES AND TECHNICAL SURVEYS

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Water Supply Paper No. 319

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Preliminary map - Townships 11 to 14, ranges 26 to 29, west
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2. Map showing topography and the location
and types of wells.

PART I

INTRODUCTION

The present report is an attempt to assemble the data on ground-water resources in a form that will be useful to well drillers, farmers, municipal authorities, and others interested in obtaining adequate water supplies.

Publication of Results

The essential information pertaining to ground-water conditions is being issued in reports that, in Manitoba, cover a square block of sixteen townships lying between the correction lines and beginning at the Saskatchewan boundary. The reports on the most southerly strip of the province include in addition the two townships lying north of the International Boundary. The secretary-treasurer of each municipality will be supplied with the information covering that municipality, and copies of the reports will also be available for study at offices of the Provincial and Federal Departments. Further assistance in interpreting the reports may be obtained by applying to the Chief Geologist, Geological Survey of Canada, Ottawa.

How to Use the Report

Anyone desiring information concerning ground-water in any particular locality will find the available data listed in the well records, and other pertinent information on the maps of the area. For those unfamiliar with these reports it is, perhaps, advisable that that part dealing with the area as a whole be read first, so as to be in a better position to understand the more particular descriptions of each township that follow. Also, the map accompanying the report should prove a useful source of reference when reading the text.

The map consists of two figures. Figure 1 shows bedrock and surface geology. The water-bearing properties of the bedrock change from formation to formation, and are referred to in subsequent pages. The type of glacial deposit at the surface may be determined from the map, and its possibilities as an aquifer are also discussed in this report.

Figure 2 shows the location and types of wells in the area, the land relief (topography), and the drainage pattern. Not every well is plotted on the map, but most of those giving pertinent information are shown, and probably include 90 per cent of the wells in the area. Where ground water is not readily available, or carries too much dissolved salts to be used, dugouts often form the only means of supply. The topography is shown by contours, or lines of equal elevation, spaced at vertical intervals of 50 feet.

The well records are compiled from data obtained by interviewing farmers, and in many cases their accuracy depends upon the farmer's memory. Wherever possible data were checked by plumb-line measurement to the nearest foot. The wells are tabulated by townships and sections, and the total depth of the well, depths to the water level at high and low stages, and, where possible, the depth at which the water-bearing horizon occurs, are all listed. The general character of the water is stated, and the use to which it can be put. Wells from which samples were taken for analysis are indicated on the well-record sheets. An idea of how much water a well can be expected to yield is suggested by the number of stock (cattle and horses only) that can be watered at it. One head is assumed to consume between 8 and 10 gallons of water a day. Unless followed by the word "only".

the figure for the number of stock watered is not necessarily the maximum yield of the well, but simply the greatest amount that the present user has required. The word "only" indicates that the figure given is the maximum yield of the well. To obtain the position of an aquifer at any given point, the elevation of the point should be determined from the contours on Figure 2 of the map. Elevations of adjacent wells may be found in the well records and the depth to the aquifer can usually be determined from them. By comparing elevations the depth of the aquifer below the unknown point may be estimated. This method is particularly applicable to bedrock wells, but may not be successful where information is too limited, or where the glacial drift is thick and of an irregular character. In such instances a person searching for water should refer to the text for information on the nature of the deposits in that area.

GLOSSARY OF TERMS USED

Alkaline. The term 'alkaline' or 'alkali' water has been applied rather loosely to waters having a peculiar and disagreeable taste, and commonly a laxative effect. The waters so described in the Prairie Provinces are those heavily charged with sulphates of magnesium and sodium (respectively Epsom salts and Glauber's salts) and are more correctly termed sulphate waters. Truly 'alkaline' waters owe that property to the presence of calcium carbonate and calcium bicarbonate. In this report an attempt to adhere to local terminology is made by referring to sulphate waters as 'alkali' in the well records, and the term 'alkaline' is avoided.

Alluvium. Deposits of clay, silt, sand, gravel, and other material in lake beds and in flood plains of modern streams. The term also includes the material in river terraces, which once formed part of the flood plain but are now above it.

Aquifer. A porous bed, lens, pocket, or deposit of material that transmits water in sufficient quantity to satisfy pumping wells and springs.

Bedrock. Bedrock, as here used, refers to partly or wholly consolidated deposits of gravel, sand, silt, clay, and marl that are older than the glacial drift.

Bentonite. and bentonitic clays have the property of swelling when water is added to them. They occur as white beds as much as 2 feet thick, but usually much thinner, and are probably formed by the weathering of volcanic ash.

Buried pre-Glacial Stream Channel. A channel eroded into the surface of the bedrock by a stream before the advance of the continental ice-sheet, and subsequently either partly or wholly filled in by sands, gravels, and boulder clay deposited by the ice-sheet or later agencies.

Coal Seam. The same as a coal bed. It is a deposit of carbonaceous material formed from the remains of plants by partial decomposition and burial.

Contour. A line on a map joining points that have the same elevation above sea-level.

Continental Ice-sheet. The great ice-sheet that covered most of the surface of Canada many thousands of years ago.

Escarpment. A cliff or relatively steep slope separating level or gently sloping areas.

Flood Plain. A flat part of a river valley ordinarily above water but submerged when the river is in flood. It is an area where silt and clay are being deposited.

Glacial Drift. A general term that includes all the loose, unconsolidated materials that were deposited by the ice-sheet, or by the waters associated with it. Clay containing boulders usually forms a large part of the glacial drift in an area, and is called glacial till or boulder clay, and is not to be confused with the more general term glacial drift, which occurs in the following several forms:

(1) Terminal Moraine or Moraine. A ridge or series of ridges formed by glacial drift that was laid down at the margin of a moving ice-sheet. The surface is characterized by irregular hills and undrained basins.

(2) Kame Moraine. Assorted deposits of sand and gravel laid down at or close to the ice margin. The topography is similar to that of a terminal moraine.

(3) Ground Moraine. Boulder clay (till) laid down at the base of an ice-sheet. The topography may vary from flat to gently rolling.

(4) Glacial Outwash. Sand and gravel plains or deltas formed by streams that issued from the continental ice-sheet.

(5) Glacial-lake Deposits. Sand, silt, and clay deposited in glacial lakes during the retreat of the ice-sheet.

Shoreline. A discontinuous escarpment, with intervening gravel beaches and bars, which indicates the former margin of a glacial lake.

Ground Water. The water in the zone of saturation below the water-table.

Hydrostatic Pressure. The pressure that causes water in a well to rise above the point at which it was first encountered in the well, namely, at the level of the aquifer.

Impervious or impermeable. Beds such as fine clays or shale are considered to be impermeable when they do not permit the perceptible passage or movement of ground water.

Pervious or Permeable. Beds are pervious or permeable when they permit the perceptible passage or movement of ground water, as in the case of sands and gravels.

Pre-Glacial Land Surface. The surface of the land as it existed before the ice-sheet covered it with drift.

Recent Deposits. Deposits that have been laid down by the agencies of water and wind since the disappearance of the continental ice-sheet; for example, alluvium in stream valleys.

Sand Point or Driven Well. A sand point is a piece of perforated and screened pipe 2 or 3 feet long, which ends in a sharp point. It is fastened to lengths of ordinary pipe and forced down into surface deposits of a sandy or gravelly nature. The depth of such a well rarely exceeds 30 feet.

Unconsolidated Deposits. The mantle or covering of alluvium, pre-glacial soils, and glacial drift consisting of loose, uncemented material that overlies the bedrock.

Variegated. Beds so described show different colours in alternating beds or lenses.

Water-table. The upper limit of the part of the ground saturated with water. This may be near the surface or many feet below it. A water-table is said to be perched when a zone of saturated material is separated from the main water-table below by a zone or zones of unsaturated material.

Water-worked Till. Glacial till or boulder clay that has been subjected to water action, usually near the margins of glacial lakes, so that the fine clay has been washed out and a deposit that may be composed mainly of sand and gravel is left behind.

Wells. The term refers to any hole sunk in the ground by any means for the purpose of obtaining water. If no water is obtained they are referred to as dry holes. Wells yielding water are divided into four classes:

- (1) Flowing Artesian Wells. Wells in which the water is under sufficient hydrostatic pressure to flow above the surface of the ground at the well.
- (2) Non-flowing Artesian (Sub-artesian) Wells. Wells in which the water is under sufficient hydrostatic pressure to raise it above the level of the aquifer, but not above the level of the ground at the well.
- (3) Non-artesian Wells. Wells in which the water does not rise above the water-table or the aquifer.
- (4) Intermittent Non-artesian Wells. Wells that are generally dry for a part of each year.

GENERAL DISCUSSION OF GROUND WATER

Almost all the water recovered from beneath the earth's surface for both domestic and industrial uses is meteoric water, that is, water derived from the atmosphere. Most of this water reaches the surface as rain or snow. Part of it is carried off by streams as run-off; part evaporates either directly from the surface and from the upper mantle of soil, or indirectly through transpiration of plants; and the remainder sinks into the ground to be added to the ground-water supplies.

The proportion of the total precipitation that sinks into the ground will depend largely upon the type of soil or surface rock, and on the topography; more water will sink into sand and gravel, for example, than into clay; if, on the other hand, the region is hilly and dissected by numerous streams, more water will be immediately drained from the surface than in a relatively flat area. Light, continued precipitation will furnish more water to the underground supply than brief torrential floods, during which the run-off may be nearly equal to the precipitation. Moisture failing on frozen ground will not usually find its way below the surface, and, therefore, will not materially replenish the ground-water supplies. Light rains falling during the growing season may be wholly absorbed by plants. The quantity of moisture lost through direct evaporation depends largely upon temperature, wind, and humidity. Locally these deposits may become very extensive. The water-bearing properties of alluvial deposits are variable, but, in general, such deposits form favourable aquifers. They are porous, and readily yield a part of their contained water, although in places their porosity may be greatly reduced by the presence of fine silt and clay. This type of deposit may be expected to yield moderate domestic supplies through shallow wells, and larger supplies if the deposits are extensive.

In some areas of relatively steep slopes, valleys have been partly filled with sand and gravel, which, in turn, have been covered with impervious clay and silt. These circumstances commonly give rise to artesian conditions in the lower part of the valley.

DISCUSSION OF WATER ANALYSES

Both the kind and quantity of mineral matter dissolved in a natural water depend upon the texture and chemical composition of the rocks with which the water has been in contact. Pollution is caused by contact with organic matter or its decomposition products. Analyses of well waters for mineral content are made by the Department of Health and Public Welfare, Winnipeg, and by the Bureau of Mines, Department of Mines and Resources, Ottawa.

As the ground-water survey of Manitoba progresses an effort is made to secure samples representative of each major aquifer encountered; the purpose of this is to compare the chemical characteristics of waters from the various geological horizons and, thereby, assist in making correlations of the strata in which the waters occur. The mineral content of natural waters is also of interest to the consumers, though the effects of the constituents are usually already apparent. The quantities of the various constituents for which tests are made are given as 'parts per million', which refers to the proportion by weight of each constituent in 1,000,000 parts of water. A salt when dissolved in water separates into two chemical units called 'radicals', and these are expressed as such in the chemical analyses. In one group are included the metallic elements of calcium (Ca), magnesium (Mg), sodium (Na), and iron (Fe), and in the other group are the sulphate (SO_4), chloride (Cl), bicarbonate (HCO_3), carbonate (CO_3), and nitrate (NO_3) radicals. The radicals listed in the analyses tabulated in the second part of this report can be combined to give the actual quantity of the particular salts present in the water, but this is not done here as the radicals alone give enough information to identify the water types. In fact, the sulphate, chloride, and carbonate radicals, plus the hardness, serve to identify a water, and crude field tests on the basis of these constituents were used in some areas to outline more completely zones of the various water types.

The following mineral constituents include all that are commonly found in natural waters in quantities sufficient to have any practical effect on the value of waters for ordinary uses:

Silica (SiO_2) is dissolved in small quantities from almost all rocks. It is not objectionable except in so far as it contributes to the formation of boiler scale.

Iron (Fe) in combination is dissolved from many rocks as well as from iron sulphide deposits with which the water comes in contact. It may also be dissolved from well casings, water pipes, and other fixtures in quantities large enough to be objectionable, but separates as the hydrated oxide upon exposure of the water to the atmosphere. Excessive iron in water causes straining on porcelain or enamelled ware, and renders the water unsuitable for laundry purposes. Water is usually considered not potable if the iron content is more than 0.5 part per million.

Calcium (Ca) in the water comes from mineral particles present in the surface deposits, the chief sources being limestone, gypsum, and dolomite. Fossil shells provide a source of calcium, as does also the decomposition of igneous rocks. The common compounds of calcium are calcium carbonate (CaCO_3) and calcium sulphate (CaSO_4), neither of which have injurious effects on the consumer, but both of which cause hardness.

Magnesium (Mg) is a common constituent of many igneous rocks and, therefore, very prevalent in ground water. Dolomite, a carbonate of calcium and magnesium, is also a source of the element. The sulphate of

magnesia ($MgSO_4$) combines with water to form 'Epsom salts,' and renders the water unwholesome if present in large amounts.

Sodium (Na) is derived from a number of the important rock-forming minerals, so that sodium sulphate and carbonate are very common in ground waters. Sodium sulphate (Na_2SO_4) combines with water to form 'Glauber's salt' and excessive amounts make the water unsuitable for drinking purposes. Sodium carbonate (Na_2CO_3) or 'black alkali' waters are mostly soft, the degree of softness depending upon the ratio of sodium carbonate to the calcium and magnesium salts. Waters containing sodium carbonate in excess of 200 parts per million are unsuitable for irrigation purposes¹. Sodium sulphate is less harmful.

¹"The extreme limit of salts for irrigation is taken to be 70 parts per 100,000, but plants will not tolerate more than 10 to 20 parts per 100,000 of black alkali (alkaline carbonates and bicarbonates)". Frank Dixey, in 'A Practical Handbook of Water Supply', Thos. Murby & Co., 1931, p. 254.

Sulphates (SO_4) referred to in this report are those of calcium, magnesium, and sodium, and have been mentioned above in referring to these radicals. They are also formed by oxidation of iron sulphides, and, hence, it is not uncommon to find iron in sulphate waters. Sulphates cause permanent hardness in water, and injurious boiler scale. Sodium and magnesium sulphates are laxative when present in quantities of more than 900 parts per million. The writers found that acclimatized people could drink water containing as much as 2,000 parts per million of all three of the principal sulphates, but that when all were present in quantities over 1,500 parts per million the water was commonly laxative to those not accustomed to it.

Chloride (Cl) is a constituent of all natural waters and is dissolved in small quantities from rocks. Waters from wells that penetrate brine or salt deposits contain large quantities of chloride, usually as sodium chloride (common salt) and less commonly as calcium chloride and magnesium chloride. Sodium chloride is a characteristic constituent of sewage, and any locally abnormal quantity suggests pollution from this source. However, such abnormal quantities should not, in themselves, be taken as positive proof of pollution in view of the many sources from which chloride may be derived. Chlorides impart a salty taste to water if present much in excess of 500 parts per million. In southwestern Manitoba waters with as much as 3,000 parts per million of chloride are used domestically, though more than 1,500 parts per million is generally considered undesirable. The following figures apply to chlorides: stock will require less salt if the water bears 2,000 parts per million; more than 5,000 parts per million is unfit for human consumption; more than 8,000 parts per million is unfit for horses; more than 9,500 parts per million is too much for cattle; and more than 15,500 parts per million is excessive for sheep. Magnesium chloride, less common than sodium chloride, is very corrosive to metal plumbing.

Nitrates (NO_3) found in ground water are decomposition products of organic materials; they are not harmful in themselves, but they do point to probable pollution. It is recommended that a bacterial test be made on water showing an appreciable nitrate content, if it is to be used for domestic purposes.

Carbonates (CO_3) in water are indicated in the table of analyses as 'alkalinity'. Calcium and magnesium carbonate cause hardness in water, which may be partly removed by boiling. Sodium carbonate causes softness in waters, and is referred to under 'Sodium' above.

Bicarbonates (HCO_3). Carbon dioxide dissolved in water renders the insoluble calcium and magnesium carbonates soluble as bicarbonates. The latter are decomposed by boiling the water, which changes them to insoluble carbonates.

Hardness is a condition imparted to waters chiefly by dissolved calcium and magnesium compounds. It here refers to the soap-destroying power of water, that is, to the amount of soap that must first be used to precipitate the above compounds before a lather is produced. The hardness of water in its original state is its total hardness, and is classified as 'permanent hardness' and 'temporary hardness'. Permanent hardness remains after the water has been boiled. It is caused by mineral salts that cannot be removed from solution by boiling, but it can be reduced by treating the water with natural softeners, such as ammonia or sodium carbonate, or with many manufactured softeners. Temporary hardness can be eliminated by boiling, and is due to the presence of bicarbonates of calcium and magnesium. Waters containing large quantities of sodium carbonate and small amounts of calcium and magnesium compounds are soft, but if the latter compounds are present in large quantities the water is hard. The following table¹ may

¹Thresh, J.C., and Beale, J.F.: The Examination of Waters and Water Supplies; London, 1925, p. 21.

be used to indicate the degree of hardness of a water:

<u>Total Hardness</u>	
<u>Parts per million</u>	<u>Character</u>
0-50.....	Very soft
50-100.....	Moderately soft
100-150.....	Slightly hard
150-200.....	Moderately hard
200-300.....	Hard
300 +	Very hard

The above table gives the generally accepted figures for hardness, but the people of southwestern Manitoba have become accustomed to harder waters, and the following table, based on about 800 field determinations of hardness, by the soap method, is more applicable:

<u>Parts per million</u>	<u>Character</u>
0-100.....	Very soft
100-150.....	Soft
150-250.....	Moderately hard
250-350.....	Hard
350-500.....	Very hard
500+	Excessively hard

Waters having a hardness of up to 300 parts per million are commonly used for laundry purposes. In southwestern Manitoba, hardness ranges from less than 50 parts per million to more than 2,500 parts per million.

PART IITOWNSHIPS 11 to 14, RANGES 26 to 29,
WEST PRINCIPAL MERIDIAN, MANITOBA
(Elkhorn Area)Introduction

An investigation of the glacial geology and the ground-water resources of townships 11 to 14, ranges 26 to 29, W. Princ. meridian, was carried on by the writer during the field season of 1949.

Physical Features

A marked topographic feature of this area is the valley of Assiniboine River, which is about a mile wide and 150 feet deep. The valley walls are gullied by short streams with narrow channels and the river itself follows an irregular course along a flat valley floor. Niso Creek flows east across the area and joins the Assiniboine in sec. 18, tp. 13, rge. 26. Gopher and Bosshill Creeks cross the southwestern part to join the Assiniboine near the town of Virden. The general character of the topography is that of an undulating plain with undrained depressions and isolated hills rising some 60 feet above the surrounding plain.

Geology

Table of Formations

Age	Formation	Character	Thickness (Feet)
Recent	Alluvium	Stream-laid mud, silt, sand, and gravel	
Pleistocene	Lake deposits	Silty clays, fine sands and silts, duned sands, assorted sands and gravel in beaches and deltas	0-50

Age	Formation	Character	Thickness (Feet)
	Glacial deposits	Till, clay, sand, gravel, boulders, assorted sand, and gravel in outwash plains	0-300
Upper Cretaceous	Riding Mountain	Upper beds of medium to light grey, hard, siliceous shales (Odanah shale), with some thin layers of fine, blue sand and bentonite beds; lower beds of slippery clay shale that tends to slump	1,000-
	Vermilion River	Dark grey and black shales comprising three members: <u>Pembina</u> (dark shale, numerous bentonite bands near base); <u>Boyne</u> (grey, calcareous shale, non-calcareous, dark shale near base); <u>Morden</u> (calcareous, speckled shale, over- lying dark grey, non- calcareous, blocky shale with thin partings of white sand)	80- 140- 190-
	Favel	Grey shale with white, calcareous material; some bands of limestone; some bentonite	150-
Lower and Upper Cre- aceous	Ashville	Dark grey to black shales with silt and sands	40-
Lower Cretaceous	Swan River	White to green sandstone, black shale, and silt	50-
Jurassic		Light grey to red shale, calcareous sandstone, grey to buff-brown shales, light grey limestone and sandstone	380-
Jurassic or earlier	Amaranth	Red beds and gypsum	220

Upper Cretaceous shale of the Riding Mountain formation underlies the area and outcrops along Assiniboine Valley and Nisco Creek. The bedrock surface is irregular, fractured, and weathered, and is overlain by some 25 feet of drift in the central part of the area. It forms a widespread aquifer that yields abundant alkali water with much iron.

Overlying the bedrock is an impervious, blue, clay-rich till that may contain lenses and pockets of sand and gravel that are water bearing. Overlying the blue clay in turn is a buff weathered, stony till of variable thickness but with an average of 25 feet.

An embayment of glacial Lake Souris along Assiniboine Valley modified the ground moraine near the eastern margin of the area. Outwash sand and gravel along the valley north of Miniota was deposited when the advance of the continental ice mass was halted and the end moraine known as Arrow Hills was formed. Patches of outwash gravel have been formed in abandoned stream channels that trend southeast across the ground moraine. They are of local extent, but are favourable sources of hard, clear water.

Water Supply

Three possible sources of ground water are present in this area, but none is continuous and, therefore, in some sections, where all three are lacking, dugouts are necessary to supply water for stock.

A shallow source of water is the surface sand and gravel along abandoned channels or in outwash along the streams and the river. An abundant supply of good water is obtained from shallow wells in such material, but unfortunately they are only found in a few places.

A deeper source supplies water to wells dug through clay to pockets or lenses of sand or gravel within the ground moraine. These wells are not satisfactory as the supply fails in seasons of drought, and in seasons of excess rainfall the wells fill with water that, upon standing, absorbs sulphates and other constituents from the clays and hence becomes bitter. These wells should be pumped out as often as possible in such seasons.

A third source of water is the weathered and fractured surface of the bedrock. This zone commonly yields abundant water, but dry holes that penetrated it are on record. The chemical composition of the water varies and it may be salty or bitter. Chemical analyses show that the water of drilled wells that are properly cased is not contaminated by seepage from the surface material and commonly the water is soft.

Township 11, Range 26. The surface of this township is relatively even, but with a slope to the east. It is covered with ground moraine that, in the eastern half, has been reworked by waters of glacial Lake Souris.

Local patches of sand and gravel, deposited along the western edge of the reworked deposits, are sources of good water sufficient for domestic use. Shallow wells in sections 14, 23, and 24 are dug in such deposits. Elsewhere water is obtained at depths of 40 to 60 feet from an aquifer of sand, gravel, or boulders underlying the blue clay. These wells have never supplied much water, and dugouts are necessary for stock. The increased annual rainfall of the last 6 years, however, has raised the water-table and most of these wells are more than half full of water. As stock are watered at dugouts only small amounts are pumped out daily. Consequently, the mineral content of the water standing in the wells in contact with blue clay has increased until some of it is unfit for drinking.

Wells dug in section 2 reach shale at 50 feet. In NE. $\frac{1}{4}$ section 20, a well drilled 136 feet penetrates blue clay and yields a potable water that rises in the well to a point 20 feet from the surface of the ground.

Township 11, Range 27. Ground moraine covers the surface of this township. The upper 20 feet or more is weathered, buff-coloured till commonly known as yellow clay, and underlying this is a clay-rich, blue till. The uneven surface is broken by isolated knolls parallel with, and west of, the 1,600-foot contour. These knolls are made up of till, with some gravel on the tops where the finer materials have been washed away. An aquifer of sand and gravel, underlying the blue clay, supplies sufficient ground water for domestic use and dugouts have been installed for a stock supply. The water is commonly alkali with much iron. An average depth of the wells dug in this township is 45 feet, and during the season that the investigation was carried out the water rose 35 feet or more in most wells. These wells will water 15 head in the dry years. They are easily pumped dry but after a few hours will refill sufficiently to allow further pumping.

Township 11, Range 28. The rolling uneven surface of this township is accentuated by abandoned stream channels and numerous undrained depressions. Bosshill and Gopher Creeks flow across it in a southeast direction. Ground moraine covers most of the township, the upper 20 feet or more of which is a weathered, buff-coloured till.

A supply of hard, commonly alkali water is obtained from wells dug 25 to 30 feet to lenses of sand or gravel in the drift. These wells yield enough water for domestic use but dugouts are required for a stock supply. Outwash gravel, found along abandoned channels, is also a source of water at shallow depth.

Township 11, Range 29. The uneven, rolling surface of this township is dissected by abandoned drainage channels.

Ten drilled wells have been recorded, some of which are no longer in use. In NW. $\frac{1}{4}$ section 3, a well was drilled 215 feet to a layer of sand and gravel below 205 feet of blue, clay-rich till. The water from this aquifer rises to a point 27 feet below the surface of the ground. In SE. $\frac{1}{4}$ section 4 and SE. $\frac{1}{4}$ section 10 the same aquifer was encountered at depths of 197 and 130 feet respectively. Drilled wells 127, 105, and 145 feet deep in SE. $\frac{1}{4}$ section 12, SE. $\frac{1}{4}$ section 14, and SE. $\frac{1}{4}$ section 22 reach a similar aquifer. In NW. $\frac{1}{4}$ section 18, a well was drilled to a depth of 242 feet. At 180 feet shale was encountered and hard, salty water from it rose to within 40 feet of the surface.

Dug wells 40 to 50 feet deep commonly yield a sufficient supply for domestic use from aquifers in the blue clay. Shallower dug wells in the southern part of the township supply adequate amounts of good water from local patches of surface gravel along abandoned stream channels. Dugouts are common throughout the township.

Township 12, Range 26. The relatively flat surface of this township slopes east to where Assiniboine River crosses sections 36 and 25. Ground moraine covers the entire township, but in the eastern half it has been modified by the waters of glacial Lake Souris. The ground moraine consists of an upper 20 feet or more of buff-coloured till overlying various thicknesses of clay-rich till. Water-bearing zones are present below the blue clay and sufficient water may also be obtained from lenses of sand or gravel within the till. The wells are commonly 39 to 40 feet deep and dugouts are needed to assure a supply for stock. In section 21, a well was drilled 100 feet through 90 feet of blue clay and 10 feet of boulders and gravel. Water rose 50 feet in the well and in a month the well was dry.

Township 12, Range 27. Drift with a flat to uneven surface covers the township to a depth of not more than 30 feet, and in places only about 15 feet. Niso Creek crosses sections 31 and 32. Wells are commonly dug to bedrock where abundant water is obtained from the fractured and weathered surface of the shale. Fine sand below the blue clay is also water bearing but forms quicksand that fills the wells. In test drilling it is common to find plenty of water, but it is of poor quality, suitable for stock only. Dugouts are common. In SW. $\frac{1}{4}$ section 1, a well drilled 85 feet yields an abundant supply of good water.

Township 12, Range 28. Isolated hills of glacial till rise 30 to 50 feet above the surrounding uneven surface of this township, and sloughs of considerable extent occur in many places. Bedrock lies within 25 feet of the surface in sections 2, 3, 9, and 16. In these sections wells were drilled to a common water-bearing zone at a depth of 87 feet. Although the water in this zone is abundant it is too salty for domestic use. Wells have also been drilled in sections 21, 24, and 25. Dug wells reach layers of sand in the drift and commonly yield water of poor quality. Dugouts are common and dams have been built in Niso Creek to retain water for stock during summer months.

Elkhorn is built on a deposit of outwash sand and gravel from which shallow, dug wells and sandpoints supply sufficient water for the town. Dug wells, 18 feet deep and 6 feet in diameter, at Elkhorn Creamery yield 10,000 gallons an hour.

Township 12, Range 29. A belt of end moraine trends southeast across the township with a hilly, uneven, and much wooded surface. The remainder of the township is covered by ground moraine with an uneven surface. Niso Creek crosses sections 35 and 36.

The supply of water in this township is not abundant and its quality is poor. All the wells are dug to layers or local pockets of sand or gravel in the blue clay and reach to depths of 35 to 60 feet. No wells have been drilled to bedrock, which would probably be reached at depths of over 150 feet, but it is doubtful if water encountered in it would be of good quality.

Township 13, Range 26. Assiniboine River meanders, in a valley about 1 mile wide, across the township from section 18 to section 1 and is joined by Arrow River in section 10. Outwash gravel occurs along Arrow River. Gravel is also common in that part of the end moraine that crosses sections 25 and 24, and a broad outwash plain of sand extends from Miniota south to the edge of the river valley. The town of Miniota is supplied with sufficient water from this aquifer. Elsewhere, in the area of ground moraine, wells are dug to lenses of sand and gravel excepting south of the Assiniboine where a supply is obtained in wells less than 25 feet deep from the weathered fractured surface of the bedrock.

Drilled wells are not common, but one in NE. $\frac{1}{4}$ section 35, 80 feet deep, reaches a bed of black sand below blue clay and yields good water but with too much iron for domestic use. Springs along the north side of the valley are used in sections 16 and 19.

Township 13, Range 27. Assiniboine River crosses the northeast quarter of the township in a broad valley over the floor of which it meanders, and some cut-offs have left ox-bow lakes. The bedrock is overlain by a buff weathered till, averaging 20 feet in thickness, with an uneven to flat surface.

Wells are dug to bedrock, from whose weathered and fractured surface an abundance of water is pumped. This water may be alkali but is commonly used for drinking as well as for stock.

Township 13, Range 28. The rolling to flat surface of this township is characterized by low undrained areas known as saline flats. These have little agricultural value but contain a concentration of the mineral constituents present in the ground water. The supply of water is not satisfactory in this township as it is neither abundant nor of good quality. Those wells in use are about 30 feet deep and commonly dug to bedrock, in the weathered, fractured surface of which water is available. No drilled wells have been recorded and the possibility of good water being found at depths of 50 feet or more in the bedrock is not too encouraging, as salt water is commonly found at such depths in the adjacent areas. Wells in patches of outwash gravel along abandoned stream channels are dug for household supplies, but not all such wells yield an abundance of water.

Township 13, Range 29. The surface of this township is uneven and hilly, isolated hills being common east of the 1,650-foot contour. Niso Creek enters the township in section 18 and leaves in section 2. Ground moraine composed of glacial till covers the township with 20 feet of buff weathered till overlying more compact clay-rich till. Patches of outwash sand and gravel are found along small abandoned channels.

The wells in this township are deeper than in those to the east, most of them being more than 50 feet. These wells are dug to lenses and pockets of sand and gravel in the clay-rich till and commonly yield sufficient water for household use. Two or more wells may be needed to assure a supply if a dugout has not been built.

In NE. $\frac{1}{4}$ section 34, an abandoned well was drilled 103 feet to a layer of black sand below blue clay and the water obtained was under sufficient pressure to rise 100 feet in the well. A dug well 14 feet deep in NE. $\frac{1}{4}$ section 24 yields good water from a layer of gravel about 5 feet thick. This well supplies the neighbouring farms with drinking water. At Manson wells have been dug 60 to 72 feet and encountered only water too alkali to use.

Township 14, Range 26. The belt of end moraine forming the Arrow Hills crosses the northeast quarter of the township. The surface of the end moraine is hilly, some hills being till and others gravel. The central part of the township is relatively flat with lakes in undrained depressions in impervious clay.

Outwash plains of sand and gravel in sections 5, 6, and 30 are excellent aquifers that are tapped in many places by sandpoints. In the end moraine pockets of gravel are sources of water of good quality. In the ground moraine that covers the rest of the township wells are dug to lenses or pockets of sand or gravel. These are 20 to 30 feet deep and yield sufficient water for domestic and stock use. More than one well is, however, needed on a farm to assure an adequate supply. In sections 24, 25, 35, and 36 wells are drilled 80 feet to a layer of sand that yields hard, clear water with some iron, sufficient for 100 head. In SE. $\frac{1}{4}$ section 14, a dry hole was drilled 485 feet, reaching shale at 134 feet. A total of 29 holes were dug 28 to 32 feet deep on this quarter, of which only four remain. These have from 10 to 12 feet of hard, clear water but may go dry in seasons of less than normal rainfall.

Township 14, Range 27. Assiniboine Valley crosses this township from section 30 to section 2. The river meanders on a wide valley floor and some meanders are cut off to form ox-bow lakes. Minnewasta Creek joins the Assiniboine in section 28. Ground moraine covers the township except near the edge of the valley where outwash gravel and sand are present.

East of the valley wells are dug in outwash sand and yield a sufficient supply for farm use. Wells in ground moraine on either side of the valley reach lenses of sand or gravel in the till that yield a small supply not sufficient for farm use and dugouts are needed. In N.W. $\frac{1}{4}$ section 25 a well drilled 109 feet through blue clay reaches an aquifer yielding hard, clear water with some iron.

Township 14, Range 28. Ground moraine covers the entire township, although it is not more than 20 feet deep in part of the southeast quarter. Its surface is uneven with undrained depressions.

The water supply is rarely sufficient and dugouts are needed on most farms. In the southwest quarter wells are dug to bedrock and an abundant supply is available in its weathered and fractured surface, but elsewhere wells are dug into glacial drift and the supply commonly fails during the winter months. At Willen a well drilled 70 feet yields alkali water from an aquifer in blue clay.

Township 14, Range 29. A narrow belt of end moraine trends southeast across the township from section 33 to section 13. This has a hilly, rolling surface that grades into the more even surface of the ground moraine covering the remainder of the township. Patches of outwash gravel along abandoned stream channels in sections 7, 13, 18, 29, and 36 are excellent aquifers and wells less than 12 feet deep into them yield an abundant supply of water. The water for most of the township is pumped from an aquifer of fine black sand below blue clay at an elevation of about 1,580 feet above sea-level. Wells 50 to 70 feet deep reach this aquifer and yield a moderate supply of water, most of which is alkali. The supply may fail in seasons of less than normal rainfall and dugouts are built to assure that sufficient water will be available at such times. In SW. $\frac{1}{4}$ section 2, a well 103 feet deep obtains water at 100 feet through the fractured surface of the bedrock.

Analyses of Water Samples

Discussion of Water Analyses

Twelve samples of water from the Elkhorn area were analysed by the Mines Branch, Department of Mines and Technical Surveys, Ottawa. The numbers in the first column are for laboratory identification only and have no special significance.

Samples Nos. 4083, 4084, 4109, 4111, and 4112 are from wells 34 to 54 feet deep, dug to lenses of sand or gravel in blue clay. The five analyses are of water of much the same type. Each has a high concentration of the constituents analysed, and hence the waters are very hard. Sample No. 4112, in particular, is of water with an exceedingly high concentration of all the constituents, and in consequence has a bitter taste and precipitates a scale on pots and pans. These samples are typical of much of the ground waters of southwestern Manitoba.

Samples Nos. 4082, 4081, and 4108 are from wells along Niso Creek that are dug 30 to 60 feet to aquifers in the bedrock. Sample No. 4082, from a drilled well 60 feet deep, is of soft water with a concentration of sodium and chlorine. Sample No. 4108, from a dug well, shows a more balanced concentration of each constituent and the water is very hard. Sample No. 4081, also from a dug well, is excessively hard water and shows a greater concentration of every constituent than in the other two samples. All three wells apparently reach the same soft-water aquifer, but only in the drilled well, which is cased, is contamination from higher, hard-water aquifers prevented.

Sample No. 4107 is of relatively soft water from an aquifer in bedrock. The well is drilled 242 feet and reaches shale at 180 feet. This is a good quality water.

Samples Nos. 4110 and 4079 are taken from wells that reach aquifers in bedrock. The wells are about $1\frac{1}{2}$ miles apart and have elevations of 1,628 and 1,634 feet respectively. Sample No. 4079 is taken from a drilled well 103 feet deep. The water is very soft, the large amounts of sodium, chlorine, and bicarbonate combining to form natural softeners for the water. This well is cased and not contaminated by the water from the overburden. Sample No. 4110 is from a dug well. Most of the water comes from the shale, but there is sufficient contamination by water from the overburden to render the water hard and alkali.

Sample No. 4080 is taken from a dug well 45 feet deep that reaches an aquifer of black sand underlying blue clay. Bedrock is about 50 feet from the surface of the ground. This water is very hard with a high concentration of sulphates.

ANALYSES OF WELL WATERS FROM TOWNSHIPS 11-14, Ranges 26-29, W.P.M., Manitoba

Sample Number	T	Section	Township	Range	Meridian	Owner	Depth of well (feet)	* Aquifer	Total dissolved solids (parts per million)	Constituents as Analysed (parts per million)								Hardness as (CaCO ₃) (parts per million)		
										Calcium (Ca)	Magnesium (Mg)	Alkalis (as Na)	Sulphate (SO ₄)	Chloride (Cl)	Nitrate (NO ₃)	Bicarbonate (HNO ₃)	Alkalinity (as CaCO ₃)	Ca hardness	Mg hardness	Total hardness
4111	NW	5	11	26	WPM	R. Stephenson	54		1658	252.0	125.0	59.0	765.0	18.2	0	536.8	440.0	628.7	514.4	1143.1
4084	SW	8	11	26	WPM	R. Sinclair	50	gr.	5253	425.0	509.3	196.0	2209.0	143.3	165.6	819.8	672.0	1257.5	2095.8	3353.3
4083	SE	22	11	26	WPM	L. Tapp	35		2220	239.0	155.6	36.0	232.9	107.3	797.4	378.2	310.0	738.5	640.3	1378.8
4109	SE	16	11	27	WPM	H. Odell	34	gr.	3914	302.5	248.7	535.0	1783.7	247.8	230.4	593.2	499.0	754.7	1023.4	1778.1
4112	SE	19	11	27	WPM	C. Dunkin	34	cl.	7978	397.3	621.7	1040.0	4355.2	572.6	0	237.9	215.0	991.3	2558.3	3549.6
4082	NE	31	12	27	WPM	R. Watson	60	sh.	3754	33.7	13.3	1430.0	641.6	1299.6	7.1	745.7	616.0	84.1	54.7	138.8
4081	SE	6	13	27	WPM	G. Cole	30	sh.	3560	257.0	281.7	224.0	563.3	260.1	886.0	872.8	715.4	984.3	1139.2	2143.5
4108	SE	34	12	28	WPM	H. Drake	50	sh.	1468	114.8	55.7	288.0	526.3	163.8	65.6	322.1	264.0	286.4	229.2	515.6
4107	NW	18	11	29	WPM	W. Goethe	242	sh.	1224	47.0	18.0	404.0	425.5	65.8	0	551.4	52.0	117.3	77.4	194.7
4110	NE	36	13	29	WPM	W. J. Kirby	45	sh.	3574	212.0	213.9	660.0	1557.2	304.5	79.7	641.7	526.0	528.9	880.2	1409.1
4029	SW	2	14	29	WPM	G. Fowler	103	sh.	2700	17.0	9.4	1040.0	44.4	1200.2	4.4	719.8	618.0	42.4	38.7	81.1
4080	NE	28	14	29	WPM	A. Elliot	45	sd.	5475	330.0	564.4	253.0	2169.6	235.4	255.2	602.2	493.6	1127.7	2322.5	3450.2

* Symbols used for aquifers: gr. - gravel
cl. - clay
sh. - shale
sd. - sand

Record of Wells

The well records of this area follow in tabulated form. A commentary on these has been made on page 1 of this report.

As a rule the depth to the 'principal water-bearing bed' has been taken as the total depth of the well, and its elevation is given as such. This commonly applies to wells drilled in bedrock or those obtaining water from sub-artesian or artesian aquifers in glacial material or bedrock formations. For these wells digging or drilling is continued until a good supply is obtained and then operations are stopped. In shallow surface materials, not over 30 feet deep, wells are usually dug a short distance below the water-table during a dry season and thereafter water may enter or leave the well at any point below the water-table. The height to which water will rise in the well depends on the amount of rainfall received during the season. For the season in which the survey was conducted the rainfall was more than normal for the district and the figures given for the height of water in the dug wells is, consequently, above average.

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GROUND-WATER RESOURCES
OF
WHITCHURCH TOWNSHIP,
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By
H. N. Hainstock, E. B. Owen, and J. F. Caley



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Illustrations

Map - Whitchurch township, York county, Ontario:

- Figure 1. Map showing bedrock formations and
 surface deposits;
- Figure 2. Map showing the topography, and location
 and types of wells.

1. The first part of the document discusses the importance of maintaining accurate records of all transactions. It emphasizes that every entry must be clearly documented, including the date, amount, and purpose of the transaction. This ensures transparency and allows for easy verification of the data.

2. The second part of the document outlines the procedures for handling discrepancies. It states that if there is a difference between the recorded amount and the actual amount, it should be investigated immediately. The document provides a step-by-step guide on how to identify the source of the error and how to correct it.

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10. The tenth part of the document discusses the importance of maintaining accurate records of all transactions. It emphasizes that every entry must be clearly documented, including the date, amount, and purpose of the transaction. This ensures transparency and allows for easy verification of the data.

Appendix A: Sample Transaction Record

Date	Amount	Description
2023-01-01	100.00	Initial deposit
2023-01-15	50.00	Payment for services
2023-02-01	200.00	Transfer from savings
2023-02-15	75.00	Payment for utilities
2023-03-01	150.00	Transfer to checking
2023-03-15	30.00	Payment for groceries
2023-04-01	120.00	Transfer from checking
2023-04-15	40.00	Payment for rent
2023-05-01	180.00	Transfer to savings
2023-05-15	60.00	Payment for insurance

INTRODUCTION

This report deals with the ground-water conditions of a township in the province of Ontario investigated by the Geological Survey of Canada. It is one of a series of ground-water reports on individual townships of Ontario.

All available information pertaining to the water wells in the area was recorded and water samples were taken for analysis. The elevation of the surface of the water in most of the wells was measured. As the ground-water conditions are directly related to the geology, the surface deposits were also studied and mapped.

Thanks are here extended to the farmers and to the residents of communities throughout the area for their co-operation and willingness to supply information regarding their wells. Valuable assistance was also given by well drillers and municipal waterworks authorities in the area.

Publication of Results

The essential information pertaining to ground-water conditions is being issued in reports covering each township investigated in the province of Ontario. These reports, as published, will be supplied directly to the proper municipal and township authorities. In addition, pertinent data on wells investigated in each township will be kept on file at Ottawa. The well record compilation sheets will not ordinarily accompany the reports, as, for most areas, they are too numerous. However, persons interested in individual wells may receive the information upon application to the Chief Geologist, Geological Survey of Canada, Ottawa. For this information the request should specify lot, concession, owner's name, and approximate location of the well -- at house, at barn, in pasture, etc.

With each report is a map consisting of two figures. Figure 1 shows the surface deposits that will be encountered in the

area, and Figure 2 shows the positions of all wells for which records are available, together with the class of the well at each location.

GLOSSARY OF TERMS USED

Alluvium. Recent deposits of clay, silt, sand, gravel, and other material deposited in lake beds and in flood-plains of modern streams.

Aquifer. A porous bed, lens, pocket, or deposit of material that transmits water in sufficient quantity to satisfy pumping wells, flowing artesian wells, and springs.

Bedrock. Bedrock, as here used, refers to the consolidated deposits underlying the glacial drift. South of a line drawn between Midland, on Georgian Bay, and Kingston, the bedrock consists mainly of sedimentary rocks such as limestone, shale, slate, and sandstone; north of that line the bedrock consists chiefly of hard, crystalline, granitic rocks.

Contour. A line drawn on a map that passes through points that have the same elevation above mean sea-level.

Continental Ice-sheet. The great, broad ice-sheet that covered most of the surface of Canada many thousands of years ago.

Escarpment. A cliff or relatively steep slope separating two level or gently sloping areas.

Effluent Stream. A stream that receives water from a zone of saturation.

Flood-plain. A flat part in a river valley ordinarily above water, but covered with water when the river is in flood.

Glacial Drift. A general term that includes all the loose, unconsolidated materials that were deposited by the continental ice-sheet, or by waters associated with it. It includes till, deposits of stratified drift, and scattered boulders and rock fragments.

Several forms in which glacial drift occurs are as follows:

(1) End Moraine (Terminal Moraine). A more or less discontinuous ridge or series of ridges consisting of glacial drift that was laid down by the ice at the margin of a moving ice-sheet. The surface is characterized by irregular hills and undrained basins.

(2) Ground Moraine. A widely distributed moraine consisting of glacial drift deposited beneath an ice-sheet. The predominant material is till, which is clay containing stones. The topography may vary from flat to gently rolling.

(3) Kame Moraine. Assorted deposits of sandy and gravelly stratified drift laid down at or close to the ice margin. The topography is similar to that of an end moraine. Kame terraces are elongated deposits of this type laid down on the slopes of broad, flat-bottomed valleys.

(4) Drumlin. A smooth oval hill that has its long axis parallel with the direction of ice movement at that place. It is composed mainly of till.

(5) Esker. An irregular-crested ridge or series of discontinuous ridges of stratified drift deposited by a glacial stream that flowed beneath the continental ice-sheet or in deep crevasses within it. It is composed mainly of sand and gravel.

(6) Glacio-fluvial Deposits. Silt, sand, and gravel outwash deposited by streams resulting from the melting of the ice-sheet.

(7) Glacio-lacustrine Deposits. Clay, silt, and sand deposited in glacial lakes during the retreat of the ice-sheet. The clay deposits are commonly very distinctly stratified in layers a fraction of an inch to one or more feet in thickness; each layer is believed to represent deposition during one summer season and one winter season.

1. The first part of the report is a general

description of the project and its objectives.

2. The second part is a detailed description of the

methodology used in the study.

3. The third part is a description of the

results of the study.

4. The fourth part is a discussion of the

implications of the study.

5. The fifth part is a conclusion.

6. The sixth part is a list of references.

7. The seventh part is an appendix.

8. The eighth part is a glossary.

9. The ninth part is a bibliography.

10. The tenth part is a list of figures.

11. The eleventh part is a list of tables.

12. The twelfth part is a list of appendices.

13. The thirteenth part is a list of references.

14. The fourteenth part is a list of figures.

15. The fifteenth part is a list of tables.

16. The sixteenth part is a list of appendices.

17. The seventeenth part is a list of references.

18. The eighteenth part is a list of figures.

19. The nineteenth part is a list of tables.

20. The twentieth part is a list of appendices.

21. The twenty-first part is a list of references.

22. The twenty-second part is a list of figures.

23. The twenty-third part is a list of tables.

24. The twenty-fourth part is a list of appendices.

25. The twenty-fifth part is a list of references.

26. The twenty-sixth part is a list of figures.

27. The twenty-seventh part is a list of tables.

28. The twenty-eighth part is a list of appendices.

(8) Kame. An isolated mound or conical hill composed of stratified sand and gravel deposited in a crack or crevasse within the ice or in a depression along the ice front.

(9) Marine Deposits. Deposits laid down in the sea during the submergence that followed the withdrawal of the last ice-sheet. They consist chiefly of clay, silt, and sand, and have emerged beaches of sand and gravel associated with them.

(10) Shoreline. A discontinuous escarpment that indicates the former margin of a glacial lake or sea. It is accompanied by scattered deposits of sand and gravel located on former beaches and bars.

Ground Water. Sub-surface water in the zone of saturation below the water-table.

Hydrostatic Pressure. The pressure that causes water in a well to rise above the point at which it was first encountered.

Influent Stream. A stream that feeds water into a zone of saturation.

Impervious or Impermeable. Beds such as fine clays or shale are considered to be impervious or impermeable when they do not permit the perceptible passage or movement of ground water.

Pervious or Permeable. Beds are pervious or permeable when they permit the perceptible passage or movement of ground water, as, for example, porous sand, gravel, and sandstone.

Porosity. The porosity of a rock is its property of containing interstices or voids.

Pre-glacial Land Surface. The surface of the land as it existed before the ice-sheet covered it with drift.

Recent Deposits. Deposits that have been laid down by the agencies of water and wind since the disappearance of the continental ice-sheet; for example, alluvium in stream valleys.

Unconsolidated Deposits. The mantle or covering of loose, uncemented material overlying the bedrock. It consists of Glacial or Recent deposits of boulders, gravel, sand, silt, and clay.

Water-table. The upper limit of the part of the ground saturated with water. This may be near the surface or many feet below it. Water may be retained above the main water-table by a zone of impervious material; such water is said to be perched and its upper limit to be a perched water-table.

Wells. Holes sunk into the ground so as to obtain a supply of water. When no water is obtained they are referred to as dry holes. Wells yielding water are divided into four classes:

(1) Flowing Artesian Wells. Wells in which the water is under sufficient hydrostatic pressure to flow above the surface of the ground at the well.

(2) Non-flowing Artesian Wells. Wells in which the water is under hydrostatic pressure sufficient to raise it above the level of the aquifer, but not above the level of the ground at the well.

(3) Non-artesian Wells. Wells in which the water does not rise above the water-table or the aquifer.

(4) Intermittent Non-artesian Wells. Wells that are generally dry for a part of each year.

Zone of Saturation. The part of the ground, below a water-table that is saturated with water.

GENERAL DISCUSSION OF GROUND-WATER

Almost all the water recovered from beneath the earth's surface for both domestic and industrial uses is meteoric water, that is, water derived from the atmosphere. Most of this water reaches the surface as rain or snow. Part of it is carried off by streams; part evaporates either directly from the surface and from the upper

mantle of the soil or indirectly through transpiration of plants; the remainder infiltrates into the ground to be added to the ground-water supplies.

The proportion of the total precipitation that infiltrates from the surface into the zone of saturation will depend upon the surface topography and the type of soil or surface rock. More water will be absorbed in sandy or gravelly areas, for example, than in those covered with clay. Surface run-off will be greater in hilly areas than in those that are relatively flat. In sandy regions where relief is great, the first precipitation is absorbed and run-off only commences after continuous heavy rains. Light rains falling upon the surface of the earth during the growing season may be wholly absorbed by growing plants. The quantity of moisture lost through direct evaporation depends largely upon temperature, wind, and humidity. Ground water in areas overlain by pervious material may be recharged by influent streams carrying run-off from areas overlain by relatively impervious material.

Because of the large consumption of ground water in settled areas, it may seem surprising that precipitation can furnish and adequate supply. However, when it is borne in mind that a layer of water 1 inch deep over an area of 1 square mile amounts to approximately 14,520,000 imperial gallons, and that the annual precipitation in this region, for example, is about 30 inches, it will be seen that each year some 435,600,000 imperial gallons of water falls on each square mile. Although it would be impossible to determine the annual recharge of the ground-water supply of the area, if it were assumed that only 10 per cent of the total precipitation, namely 43,560,000 gallons, is contributed to the zone of saturation, it will be seen that the annual recharge for the entire area would be a very large volume. The annual consumption

of water in all areas investigated is not known, but an estimate for some restricted areas, based on per capita consumption, shows it to be only about one-tenth of the annual recharge as estimated above.

In most regions of the world where precipitation is effective there is an underground horizon known as the ground-water level or water-table, which is the upper surface of the zone of saturation. The water-table commonly is a subdued replica of the surface topography. The water that enters from the surface into the unconsolidated deposits and rocks of the earth is drawn down by gravity to where it reaches the zone of saturation or comes in contact with a relatively impervious layer. Such a layer may stop further downward percolation, resulting in perched water and creating a perched water-table. If a water-table is at or near the surface, there will be a lake or swamp; if it is cut by a valley, there will be a stream in the valley. The terms influent and effluent are used with reference to streams and their relation to the water-table. An influent stream flows above the water-table and feeds water into the zone of saturation; an effluent stream flows at or below the water-table and receives water from the zone of saturation. An effluent stream may become influent and eventually dry up if the water-table is lowered sufficiently. The ground water in the zone of saturation is almost constantly on the move percolating towards some point of discharge, which may be a spring or a pumping well.

All rocks and soils are to some degree porous, that is, the individual grains or particles of which they are composed are partly surrounded by minute interstices or open spaces that form the receptacles and conduits of ground water. In most rocks and soils the interstices are connected and large enough for the water to move from one opening to another. In some rocks or soils, however, they are largely isolated or too small to allow movement of water. The

porosity of a material varies directly with the size and number of its interstices, which in turn depend chiefly upon the size, shape, arrangement, and degree of assortment of the constituent particles. Horizons within the earth's crust of fine-grained rock such as shale, limestone or dolomite, or unconsolidated clay or silt, may have such small interstices that the contained water will not flow readily and wells penetrating them may derive little or no water from them. Such horizons are considered impervious. Beds of more coarse-grained materials such as sand, gravel, or sandstone have greater porosity and readily yield their waters to wells. They are called water-bearing beds or aquifers. A clean water-bearing gravel is one of the best sources of water. This is true whether the water is derived from the zone of saturation or from a bed of gravel confined above, between, or below beds of less pervious material.

Consolidated rocks usually considered to be impervious may sometimes produce water in relatively good supply from openings within them of primary or secondary origin. Those of primary origin, original interstices, were created when the rocks came into existence as a result of the processes by which they were formed; e.g. bedding planes, and intergranular spaces. Secondary interstices comprise joints and other fracture openings, solution openings, and openings produced by several processes of minor importance, such as the work of plants and animals, mechanical erosion, and recrystallization; all of these involve movement of a type that acted after the consolidation of the rock. The most important interstices with respect to water supplies are the original interstices, next to them are the fracture and solution openings.

The most common wells and those that in drift-covered areas yield the largest aggregate supply of ground water are water-table wells. These are wells that derive their water from the zone of

saturation. Many shallow wells become dry during the late summer and winter, or during periods of extreme drought. In most cases this is due to the lowering of the water-table below the bottom of the well. The grouping together of a number of water-table wells within a limited area will also lower the yield of any one of the wells. This is especially true of water-producing formations of low permeability. When a well penetrates an aquifer confined by impervious beds, water will be forced upward by hydrostatic pressure exerted at the point where the well enters the aquifer. If the hydrostatic pressure is great enough to force the water to or above the surface, a flowing well is formed.

Springs are formed where the water-table, or some water-bearing aquifer, outcrops at the surface of the ground. The water emerging from water-table springs is free-running water flowing down the gradient of the water-table. In many cases these springs occur as slow seeps along the steeper slopes of stream valleys. A large number in one area could maintain a swamp. A group of permanent springs occurring in one area could provide sufficient water to maintain a lake or form the source of a stream.

GENERAL DISCUSSION OF GROUND-WATER ANALYSIS

The mineral content of ground water is of interest to many besides those industries seeking water of specific quality. Both the kind and quantity of mineral matter dissolved in natural water depend upon the texture and chemical composition of the rocks with which the water has been in contact. Pollution is caused by contact with organic matter or its decomposition products. Analyses of well waters for mineral content are made by the Mines Branch, Department of Mines and Technical Surveys, Ottawa.

In any given area, an attempt is made to secure samples of water representative of all major aquifers. The quantities of the

various constituents for which tests are made are given as "parts per million", which refers to the proportion by weight of each constituent in 1,000,000 parts of water.

The following mineral constituents are those commonly found in natural waters in quantities sufficient to have a practical effect on the value of the waters for ordinary uses:

Silica (SiO_2) may be derived from the solution of almost any rock-forming silicate, although its chief source is the feldspars. It is commonly determined in the analysis of water for use in steam boilers, as silica is classed as an objectionable encrustant.

Calcium (Ca). The chief source of calcium dissolved in ground water is the solution of limestone, gypsum, and dolomite. The common compounds of calcium are calcium carbonate (CaCO_3) and calcium sulphate (CaSO_4), neither of which has injurious effects upon the consumer, but both of which cause hardness and, the former, boiler scale.

Magnesium (Mg). The chief source of magnesium in ground water is dolomite, a carbonate of calcium and magnesium. The sulphate of magnesium (MgSO_4) combines with water to form Epsom-salts ($\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$), and renders the water unwholesome if present in large amounts.

Sodium (Na) is found in all natural waters in various combinations, though its salts constitute only a small part of the total dissolved mineral matter in most waters in humid regions. Sodium salts may be present as a result of pollution by sewage, or of contamination by sea water either directly or by that enclosed in sediments of marine origin. Moderate quantities of these salts have little effect upon the suitability of a water for ordinary uses, but water containing sodium in excess of about 100 parts per million must be used with care in steam boilers to prevent foaming. Waters containing large quantities of sodium salts are injurious to crops and are, therefore, unfit for irrigation. The quantity of sodium salts

may be so large as to render a water unfit for nearly all uses.

Potassium (K), like sodium, is derived originally from the alkaline feldspars and micas. It is of minor significance and is sometimes included with sodium in a chemical analysis.

Iron (Fe) is almost invariably present in well waters, but rarely in large amounts. Salts, or compounds, of iron are dissolved from many rocks as well as from iron sulphide deposits with which the ground water comes in contact. It may also be dissolved from well casings, water pipes, and other fixtures in quantities large enough to be objectionable. Upon exposure of the water to the atmosphere, dissolved iron separates as the hydrated oxide that imparts a yellowish brown discoloration. Excessive iron in water causes staining on porcelain or enamelled ware and renders the water unsuitable for laundry purposes. Water is not considered drinkable if the iron content is more than 0.5 parts per million.

Sulphates (SO_4). Deposits of gypsum ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$) are the principal source of sulphates dissolved in ground water; soluble sulphates, chiefly of magnesium and sodium, are other sources. Sulphates cause permanent hardness in water and form injurious boiler scale. Sodium and magnesium sulphates are laxative when present in quantities of more than 900 parts per million.

Chloride (Cl) is derived chiefly from organic materials or from marine rocks and sediments. It occurs usually as sodium chloride and less commonly as calcium chloride and magnesium chloride. Sodium chloride is a characteristic constituent of sewage and a locally abnormal amount suggests pollution. However, because chlorides may be derived from many sources, such abnormal quantities should not, in themselves, be taken as positive proof of pollution. Chlorides impart a salty taste to water if they are present in excess of 300 parts per million.

Nitrates (NO_3) are of minor importance in the study of ground water. Relatively large quantities in a water may represent

pollution by sewage, or drainage from barnyards, or even from fertilized fields. It is recommended that a bacteriological test be made of water showing an appreciable nitrate content if it is to be used for domestic purposes.

Carbonate (CO_3) forms a large percentage of the solid compounds held in solution by the average ground water. The two chief sources are the decomposition of feldspars and the solution of limestone by water carrying carbonic acid in solution, which is the primary agent in rock decomposition. They are indicated in the table of analyses as alkalinity. Calcium and magnesium carbonates cause hardness in water, whereas sodium carbonate causes softness.

Bicarbonate (HCO_3). Carbon dioxide dissolved in water renders the insoluble calcium and magnesium carbonates soluble as bicarbonates. Boiling reverses the process by changing the bicarbonates into insoluble carbonates, which form a coating on the sides of cooking utensils.

Total Dissolved Solids (Residue on Evaporation). The term is applied to the residue obtained when a sample of water is evaporated to dryness. Waters are considered high in dissolved mineral solids when they contain more than 500 parts per million, but may be accepted for domestic use up to that point if no better supply is available. Residents, accustomed to the waters, may use waters that carry well over 1,000 parts per million of total dissolved solids without inconvenience, although persons not used to such highly mineralized waters would find them objectionable.

Hardness is a condition imparted to waters chiefly by dissolved calcium and magnesium compounds. It here refers to the soap-destroying power of water, that is, the power of the water

first to use a certain amount of soap to precipitate the above compounds before a lather is produced. The hardness of water in its original state is its total hardness. Permanent hardness remains after the water has been boiled, and is caused by mineral salts that cannot be removed from solution by boiling. It can be reduced by treating the water with natural softeners, such as ammonia or sodium carbonate, or with many manufactured softeners. Temporary hardness can be eliminated by boiling, and is due to the presence of bicarbonates of calcium and magnesium. Waters containing larger quantities of sodium carbonate than of calcium and magnesium compounds are soft, but if the latter compounds are more abundant the water is hard. The following table¹ may be used to indicate the degree of hardness of a water;

<u>Total Hardness</u>	
<u>Parts per million</u>	<u>Character</u>
0-50	Very soft
50-100	Moderately soft
100-150	Slightly hard
150-200	Moderately hard
200-300	Hard
300 and over	Very hard

¹ Thresh, J. C., and Beale, J. F.; The Examination of Waters and Water Supplies, p. 21, London, 1925.

PART II

WHITCHURCH TOWNSHIP, YORK COUNTY, ONTARIO

Physical Features

Whitchurch township, an area of approximately 103 square miles, is in the east-central part of York county, southwestern Ontario. Its eastern boundary is the county line between Ontario and York counties, and its western boundary is Yonge Street. It is bounded on the north by East Gwillimbury township and on the south by Markham township.

The greater, northern, part of the area has rolling topography characterized by abrupt hills and deep, basin-like hollows. The southern part of the area is flat or gently undulating; smaller flat areas occur in the north-central part of the township and to the north of Musselman Lake, the latter being a sandy plain. A well-marked divide extends across the township 2 to 4 miles north of, and parallel with, the southern boundary of the township. It forms a part of the height of land between Lake Simcoe and Lake Ontario.

A number of small lakes occur throughout the southern part of the area. The largest of these are Wilcocks, Bond, St. George, and Ressor Lakes in the southwestern part of the township, and Musselman Lake in the east-central part of the area. Wilcocks Lake is the headwaters of East Branch Humber River. The township is drained by Humber, Holland, and Black Rivers, and by the headwaters of Rouge and Little Rouge Rivers. Holland River heads to the west of Musselman Lake and flows in a westerly direction to near Aurora where it bends sharply to the north, continuing in that direction until it leaves the township at Newmarket. It occupies a narrow, shallow valley from its head to Aurora, but from Aurora to Newmarket its valley is wide and fairly shallow. Two large tributaries of the Holland River flow in a northwesterly direction across the northwest corner of the township. Black River and Vivian Creek head in the northeastern part of the area and drain northward into Lake Simcoe. Several small streams that form the headwaters of Rouge and Little Rouge Rivers flow in a southerly direction from the height of land and drain the southern part of the area.

The township as a whole has a relief of more than 450 feet. The highest elevation is in the eastern part of the height of land, con. IX, lots 13 to 14, where an elevation of 1,225 feet above sea-level is attained. In its western part the height of land has an elevation of more than 1,075 feet. The elevation of land decreases gradually to the north and south of the height of land, being approximately 900 feet above sea-level along the eastern part of the northern boundary, 772 feet at the town of Newmarket, and 800 feet along the central part of the southern boundary of the township.

The mean annual temperature of the area is 44.2 degrees Fahrenheit. Normal annual precipitation is 28.4 inches with the greatest amount of precipitation during the months of June, July, September, and November. These figures were reported for Aurora, in the western part of the township.

Geology

Bedrock Formations. Bedrock does not outcrop in Whitchurch township and the type of bedrock that immediately underlies the drift is not definitely known. A general discussion of bedrock geology of the area is included in Part I of this report.

Unconsolidated Deposits. In the Toronto region, some 20 miles south of Whitchurch township, there is evidence of at least three successive advances and retreats of the continental ice-sheet. There, three distinct deposits of glacial till, separated by interglacial deposits of stratified sand and clay, are exposed in the lake-shore bluffs. In Whitchurch township, however, only those deposits laid down during the last movement of the ice-sheet are exposed at the surface. Older deposits of glacial drift and interglacial deposits doubtless compose some of the great thickness of glacial drift that is known to exist in this area.

In lot 4, con. I, a deep well drilled on the farm of J. H. C. Durham, Bond Lake, penetrated 570 feet of glacial drift before bedrock was encountered. This is the only locality in the township where the thickness of the drift is definitely known, but some conception of the thickness of drift at different places in the area can be ascertained from the following table:

Thickness of the Glacial Drift

Well No.	Concession	Lot	Depth to bedrock(feet)
6	1	2	166 +
	1	4	570
58	1	5	200 +
3	1	11	185 +
11	1	19	260 +
46	1	35	336 +
19	11	5	160 +
8	11	19	170 +
48	11	34	265 +
3	111	7	120 +
15	111	24	200 +
29	111	35	127 +
10	1V	2	107 +
1	1V	11	190 +
10	1V	19	201 +
8	1V	28	200 +
3	V	1	115 +
19	V	10	195 +
11	V	32	150 +
11	VI	5	87 +
9	VI	14	114 +
8	VI	24	110 +
20	VII	4	90 +
6	VII	12	160 +
7	VII	35	115 +
1	VIII	5	100 +
15	VIII	14	150 +
7	VIII	22	160 +

Well No.	Concession	Lot	Depth to bedrock(feet)
9	VIII	35	175 +
18	IX	14	159 +
7	IX	24	180 +

NOTE: The depths marked with a + sign indicate that the total thickness of glacial drift was not penetrated.

Two large lobes originating in a single ice-sheet laid down the uppermost deposits of glacial drift in Whitchurch township. The northern ice-lobe moved southward from the Georgian Bay district and the southern lobe moved northward from Lake Ontario. Glacial drift deposited by the southern lobe of ice appears to overlap the deposits of the northern lobe and to differ from them in composition.

All the glacial drift deposited by the advancing ice-sheet and from the base of the ice during its melting constitutes the ground moraine. All of lots 1 to 5, cons. III to X, and most of lots 6 to 8 of the same concessions are mantled by ground moraine deposited by the southern ice-lobe. It is composed mainly of boulder clay, or till, but pockets, lenses, and extensive layers of water-lain sand and gravel are fairly numerous within the material, especially in the vicinity of Stouffville. The boulder clay consists of buff to blue clay with embedded pebbles and boulders of Trenton limestone, Gloucester shale, and some Precambrian rocks. Most of the material appears to have been derived locally.

A small area in the northeast corner and another fairly large area in the north-central part of the township are mantled by ground moraine deposited by the northern ice-lobe. It is quite probable that some of the deposits between Aurora and Newmarket, which have been shown on the map as terminal moraine, may be ground moraine, but the rugged topography in this area suggests that the former interpretation is the more probable. The ground moraine in the northern part of the township is of much the same composition as that in the southern part, except that it is generally more sandy or silty and much of it is well stratified. It contains more Precambrian pebbles than that in the southern part and little or no Gloucester shale. Pockets of water-laid sand and gravel are common within the till, but appear to be less numerous than in the ground moraine of the southern part of the township. Terminal moraines formed by both the northern and southern ice-lobes, and which are more or less intermingled in an interlobate area, cover the greater part of the township. These moraines have been described by F. B. Taylor.^{1, 2}

¹The Moraine Systems of Southwestern Ontario; Trans., Canadian Institute, Toronto, 1913.

²Moraines north of Toronto; Ont. Dept of Mines, vol. XLI, pt. VII, 1932, pp. 56-60.

The terminal moraine deposited by the southern ice-lobe is approximately $2\frac{1}{2}$ miles in width and extends from the southeast

corner of the area easterly across the township. The limits of its rough terrain are fairly well defined. Small lakes, among them Haynes Lake and Ressor Lake, are contained in some of the deep depressions that characterize the moraine topography. The material of the moraine is mainly boulder clay, but sand and gravel are not uncommon. A large area that is covered by stratified sand and gravel occurs in the southwest corner of the township, and several large deposits of gravel and sand occur immediately south and east of Musselman Lake. Pockets and lenses of sand and gravel appear to be fairly common, and in the eastern half of the area more or less continuous layers or tongues extend from the terminal moraine out under the ground moraine. A considerable amount of sand and gravel is encountered in deep drilled wells in most of the area covered by the terminal moraine.

The limits of the terminal moraine deposited by the northern ice-lobe are not so well defined. The front of this moraine is easily recognized north of Wilcocks Lake, but it is less distinct farther east. In the area to the north of Wilcocks Lake and that mapped as terminal moraine between Aurora and Newmarket, the material consists mainly of boulder clay, but elsewhere, except for some knolls of boulder clay, the predominant materials of this moraine are stratified silt, sand, and gravel. Sand and gravel also occurs as pockets, lenses, or fairly extensive layers in the boulder clay.

Streams that issues from the fronts of the ice-lobes during their melting transported large quantities of silt, sand, and gravel, and part of this material was deposited as outwash fans or plains in front of the moraines. In some areas the outwash materials are partly covered by glacial till due to a minor readvance of the ice-sheet. Where the streams issued from ice tunnels or ice channels, especially in areas of terminal moraine, the silt, sand, and gravel was locally bunched in hills or knolls known as kames. The outwash materials are mostly in the form of kames, but in a large flat area to the north of Musselman lake they constitute a sand plain. Kames also occur in a small area to the south of Wilcocks Lake and in an area of considerable width that extends from south of Aurora easterly to Vandorf and then northeasterly through Vivian. An old drainage channel that is occupied in part by Holland River can be traced from Musselman lake westward passing south of Aurora. It marks the course of a large river that flowed between the fronts of the ice-lobes and probably was instrumental in depositing much of the sand and gravel there. In some places the sand deposits are at least 135 feet thick. Some of the outwash material is undoubtedly from the southern terminal moraine, but the greater part of it appears to have come from the north and northeast.

Some alluvium occurs along Rouge River and its large tributary in lots 1 to 3, cons. IV and V, and alluvium may occur in parts of the Holland River Valley, although none has been shown there on the map. The flat valley that contains Wilcocks and St. George Lakes and the headwaters of Humber River is covered by thin deposits of sand mapped as alluvium.

Water Supply

The boulder clay constituting the ground moraine is not a good source of water as most of it is so compact that water soaks into or out of it very slowly, being held there by molecular attraction. Little water is, consequently, recoverable by wells. Where the boulder clay or till is sandy it may, however, prove to be a fair source of water. In some places water may follow small more or less tubular openings in the clay, and most wells that encounter these openings yield a fairly large supply of water. These openings in the clay probably connect with lenses or pockets of porous, water-bearing sand or gravel within the till that are themselves good sources of water. They are very porous, and collect and store large quantities of water that is readily yielded to wells.

The boulder clay constituting the terminal moraines has the same water-bearing properties as that of the ground moraine, and similarly the lenses of sand and gravel located therein absorb and store large quantities of water, much of which is readily recoverable by wells. In some areas, however, the sand may be so fine that wells become plugged and are rendered useless.

The outwash materials consisting chiefly of silt, sand, and gravel are very porous and absorb most of the precipitation that falls on them. Much of this water is readily recoverable by wells, especially if the deposits consist of coarse sand or gravel. If, however, the materials are composed of silt or fine sand the wells tend to plug, and are rendered useless.

Alluvium in Whitchurch township is not an important source of water as the deposits are shallow and not extensive.

The position of the water-table does not remain constant but fluctuates during the year and from year to year. The decline in precipitation during the period 1930-36 resulted in the lowering of the water-table, and a considerable number of shallow wells became dry. The water levels in a number of wells, in Whitchurch and adjoining townships, were measured periodically from June to September of 1937 and for some wells also in August 1936. The results are given in the following table. These wells were not in use so that the fluctuations in water levels is believed to be the direct result of precipitation, evapo-transpiration, and other natural causes. A considerable amount of precipitation occurred during the months that the wells were measured.

Fluctuations of the Water Level in Selected Wells

Location of well		Township	Depth of well (feet)	Date of measurement	Depth of water (feet)
Con.	Lot				
R.I	9	Pickering	55	Aug. 12, 1936	35.0
				June 5, 1937	4.5
				July 19, 1937	6.4
				Aug. 27, 1937	7.7
				Sept. 24, 1937	9.3
R.I	9	Pickering	30	Aug. 21, 1936	20.0
				June 5, 1937	5.1
				July 19, 1937	7.6
				Aug. 27, 1937	10.3
				Sept. 24, 1937	11.3

The first part of the document discusses the importance of maintaining accurate records of all transactions. It emphasizes that every entry, no matter how small, should be carefully documented to ensure the integrity of the financial data. This includes recording dates, amounts, and the nature of the transactions.

The second part of the document provides a detailed breakdown of the various types of transactions that may occur. It categorizes them into different groups, such as sales, purchases, and transfers, and explains how each should be properly recorded. This section also includes examples of how to format entries to ensure clarity and consistency.

The third part of the document discusses the importance of regular reconciliation. It explains that comparing the recorded transactions with the actual bank statements and other external records is essential for identifying any discrepancies. This process helps to catch errors early and ensures that the financial records are always up-to-date and accurate.

The fourth part of the document provides a summary of the key points discussed in the previous sections. It reiterates the importance of accuracy, proper categorization, and regular reconciliation. It also includes a final note about the importance of keeping all records for a sufficient period of time to allow for future audits and reviews.

Date	Description	Amount	Account	Balance
1/1/2024	Opening Balance	1000.00	General Fund	1000.00
1/5/2024	Received from John Doe	50.00	General Fund	1050.00
1/10/2024	Paid to Jane Smith	25.00	General Fund	1025.00
1/15/2024	Received from ABC Corp	150.00	General Fund	1175.00
1/20/2024	Paid to XYZ Inc	75.00	General Fund	1100.00
1/25/2024	Received from DEF Ltd	30.00	General Fund	1130.00
1/30/2024	Paid to GHI Corp	40.00	General Fund	1090.00
2/1/2024	Received from JKL Inc	60.00	General Fund	1150.00
2/5/2024	Paid to MNO Ltd	20.00	General Fund	1130.00
2/10/2024	Received from PQR Corp	80.00	General Fund	1210.00
2/15/2024	Paid to STU Inc	35.00	General Fund	1175.00
2/20/2024	Received from VWX Ltd	45.00	General Fund	1220.00
2/25/2024	Paid to YZA Corp	15.00	General Fund	1205.00
2/28/2024	Received from BCD Inc	55.00	General Fund	1260.00
3/1/2024	Paid to EFG Ltd	25.00	General Fund	1235.00
3/5/2024	Received from HIJ Corp	70.00	General Fund	1305.00
3/10/2024	Paid to KLM Inc	30.00	General Fund	1275.00
3/15/2024	Received from NOP Ltd	65.00	General Fund	1340.00
3/20/2024	Paid to QRS Corp	40.00	General Fund	1300.00
3/25/2024	Received from TUV Inc	50.00	General Fund	1350.00
3/30/2024	Paid to WXY Ltd	20.00	General Fund	1330.00
3/31/2024	Received from ZAB Corp	75.00	General Fund	1405.00

Location of well		Township	Depth of well (feet)	Date of measurement	Depth of water (feet)
Con.	Lot				
VIII	18	Pickering		July 24, 1936 June 5, 1937 June 21, 1937 July 19, 1937 Aug. 27, 1937	4.0 3.5 3.1 5.4 7.2
I	1	Scarborough	16.8	Aug. 3, 1936 June 7, 1937 June 21, 1937 July 19, 1937 Aug. 27, 1937 Sept. 24, 1937	11.0 5.7 6.3 7.7 9.7 10.9
II	25	Scarborough	44.7	Aug. 29, 1936 June 7, 1937 July 19, 1937 Aug. 27, 1937 Sept. 24, 1937	41.0 37.2 37.3 36.6 37.4
IV	28	Scarborough	41.3	Sept. 7, 1936 June 7, 1937 July 19, 1937 Aug. 27, 1937 Sept. 24, 1937	18.0 7.9 8.1 9.6 12.4
IV	14	Scarborough	17.6	July 29, 1936 June 7, 1937 July 19, 1937 Aug. 27, 1937 Sept. 24, 1937	15.0 5.0 5.5 5.6 6.2
VIII	10	Markham	33.4	June 8, 1937 July 19, 1937 Aug. 27, 1937 Sept. 24, 1937	18.0 18.9 18.4 20.0
V	11	Markham	17.3	June 8, 1937 July 19, 1937 Aug. 27, 1937 Sept. 24, 1937	2.6 3.0 3.7 4.7
I	4	Whitchurch	16.3	Aug. 31, 1936 June 8, 1937 July 19, 1937 Aug. 27, 1937 Sept. 24, 1937	6.0 4.9 4.1 6.2 7.2
IV	14	Whitchurch	32.3	Aug. 25, 1936 June 8, 1937 July 19, 1937 Aug. 27, 1937 Sept. 24, 1937	20.0 6.5 13.5 19.1 20.8
I	22	Vaughan	19.2	Sept. 5, 1936 June 8, 1937 July 19, 1937 Aug. 27, 1937 Sept. 24, 1937	16.0 10.3 13.3 14.4 16.2
IX	15	Vaughan	16.1	Sept. 21, 1936 June 9, 1937 July 12, 1937 Aug. 27, 1937	5.0 5.7 6.9 9.4

Date	Description	Amount
1912		
Jan 1	Balance	100.00
Jan 2	Jan 3	Jan 4
Jan 5	Jan 6	Jan 7
Jan 8	Jan 9	Jan 10
Jan 11	Jan 12	Jan 13
Jan 14	Jan 15	Jan 16
Jan 17	Jan 18	Jan 19
Jan 20	Jan 21	Jan 22
Jan 23	Jan 24	Jan 25
Jan 26	Jan 27	Jan 28
Jan 29	Jan 30	Jan 31
Feb 1	Feb 2	Feb 3
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Feb 13	Feb 14	Feb 15
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Feb 28	Feb 29	Feb 30
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Mar 31	Mar 31	Mar 31
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Apr 28	Apr 29	Apr 30
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Dec 10	Dec 11	Dec 12
Dec 13	Dec 14	Dec 15
Dec 16	Dec 17	Dec 18
Dec 19	Dec 20	Dec 21
Dec 22	Dec 23	Dec 24
Dec 25	Dec 26	Dec 27
Dec 28	Dec 29	Dec 30
Dec 31	Dec 31	Dec 31

The conditions that produce flowing-artesian wells, both in bedrock and glacial drift, are many. They have been fully described by T. C. Chamberlain¹, L. L. Fuller², Howard E. Simpson³,

¹The Requisite and Qualifying Conditions of Artesian wells; U. S. Geol. Surv., 5th Ann. Rept., 1884, pp. 125-173.

²Summary of the Controlling Factors of Artesian Flows; U. S. Geol. Surv., Bull. 319.

³Geology and Ground-water Resources of North Dakota; U. S. Geol. Surv., Water-supply Paper 598, pp. 46-48.

and others. The essential conditions necessary for the existence of flowing-artesian wells are as follows: (1) An adequate supply of water in the intake area, i.e., the locality where the water enters the ground; (2) confining beds of some relatively impervious material that overlie the water-bearing beds and prevent the upward passage of the ground water; (3) the elevation of the intake area should be greater than that of the ground surface in the locality where the well penetrates the aquifer containing the water under pressure.

The areas in which the flowing-artesian wells occur are chiefly in the south part of the township. The aquifers producing the flow-artesian wells are believed to be directly connected with the terminal moraines. These water-bearing beds consist chiefly of sand and gravel and extend from the higher ground in the terminal moraine areas to points below the till of the ground moraine. Precipitation falling on the terminal moraines enters the ground and follows down its hydraulic gradient along the more permeable beds to points where it is confined below the till of the ground moraine. The pressure of the confined water is sufficiently great to cause it to rise into any well that may penetrate the beds in which it exists.

Thirty holes in the township failed to encounter water, and of these only six were sunk to depths greater than 100 feet. In the northwestern part of the township some difficulty is experienced in obtaining adequate supplies of water at shallow depths, but elsewhere little difficulty should be experienced in obtaining sufficient water for all farm and municipal needs at depth. All the wells and springs derive their water supply from the drift, mainly from pockets, lenses, and layers of sand and gravel within the till. Only one well is known to have been drilled into bedrock.

Drilling into the bedrock formations that underlie Whitchurch township in search for water is not advised as they lie at great depth and most of the water they yield is too saline to be used for farm or municipal use. A 1,292-foot well drilled in lot 4, con. I, on the farm of J. H. C. Durham, in search of gas and oil, encountered bedrock at a depth of 570 feet. Water was obtained from the Trenton limestone at a depth of 1,145 feet, but no information was secured as to the quantity.

Data on this well are not listed in the well compilation sheets, but it has been described by R. B. Harkness¹.

¹40th Annual Report of the Ontario Department of Mines, 1931, Pts. IV and V, p. 51.

With the exception of the area in the northwest corner of the township mentioned earlier, where deposits of sand and gravel in the upper part of the drift are scarce, little difficulty is experienced in obtaining water at depths down to 80 feet. Where sand and gravel deposits occur at the surface or are overlain by a thin covering of boulder clay, few shallow wells fail to encounter water in sufficient quantity for most farm needs. This is typical of the southeastern part of the area where the supply is particularly abundant. In those areas where the deposits of sand and gravel do not appear at the surface, there is no way of determining their location and extent except by sinking wells or test holes.

In some parts of the township, particularly in the northeast corner, difficulty may be experienced during drilling in controlling the fine sand that forms the water-bearing beds and in all probability screens will have to be utilized in wells penetrating these beds to ensure a sufficient supply of ground water.

At least 80 flowing-artesian wells exist in the area covered by lots 6 to 8, cons. IV and V, lots 1 to 8, cons. VI, VII, VIII, and the western part of con. IX. The wells vary in depth from 20 to approximately 100 feet, most being between 50 and 90 feet, and tap water-bearing beds of sand and gravel. In at least two places in this area two water-bearing horizons are known to exist. In lot 7, con. VI, on the farm of A. Neighorn, water under sufficient pressure to overflow the surface was encountered in sandy material overlying clay or "hardpan" at a depth of approximately 30 feet. A much stronger flow of water was obtained by drilling through the "hardpan" into fairly coarse gravel that occurs at a depth of 70 to 80 feet. It is reported that similar conditions exist in lot 4, con. VIII, on the property used by a goldfish supply company. During the summer of 1937, a well drilled by Rofrey Bros. for the Stouffville water works in lot 8, con. VIII, encountered water in fine sand at a depth of approximately 20 feet with sufficient pressure to flow at the surface. At a depth of approximately 90 feet, however, a medium coarse gravel was encountered that did not contain water. It is thought that this is similar to the deposit of gravel which is the source of the ground water for the flowing artesian wells to the south and southeast. It is not definitely known if the deposits of sand and gravel that form the water-bearing beds of the flowing wells in this area occur as continuous layers or as separate tongues extending southward from the terminal moraine. The former is probably true as most wells drilled in this district encounter water under sufficient pressure to overflow the surface. The water-bearing beds slope up northward into the terminal moraine and the difference in elevation between it and the well sites is the cause of the pressure. The water barely overflows the surface in many wells, but in others the piezometric surface is from 1 to 15 feet above the ground surface, and the

volume of ground water produced is reported to be from 10 to not less than 40 gallons an hour. Very little difficulty should be experienced in locating an abundant supply of usable water in the southeastern part of the township. Not all wells will flow, but the water should rise a considerable distance in the wells. Water from deeper wells may contain a considerable amount of iron.

At least 31 flowing-artesian wells are known to occur in the northwest corner of the township, in lots 26 to 35, con. I, lots 28 to 35, con. II, and lots 31 to 35, in the western part of con. III. Most of these wells are from 120 to 160 feet deep, but a few are less than 75 feet deep and some are over 200 feet deep. At least two water-bearing horizons occur in this area.

Seven wells derive water from sand that underlie blue clay at depths of 24 to 72 feet. The water is under sufficient pressure to overflow the surface, rising 3 feet above it in some places. This bed does not, however, appear to be continuous throughout the locality, as many wells passed through these horizons without encountering water. Other water-bearing deposits occur in narrow bands filling old drainage channels buried by drift that slope upward into the terminal moraine to the south. The water in these is of good quality and fairly abundant in quantity, being ample for all local requirements.

The main supply in this northwest corner of the township occurs in sand or gravel at depths of 120 to 160 feet. These deposits are overlain by impervious blue clay and, in most but not all cases, the gravel underlies the sand. The aquifers for the deeper wells appear to be fairly continuous and probably underlie most, if not all, of the area in which flowing-artesian wells occur. Proof that several wells derive water from the same horizon is shown by the fact that the supply from some wells was appreciably decreased when the wells used by the town of Newmarket were drilled, especially the new well drilled in 1937. The water from this horizon is under considerable pressure and rises 1 foot to 5 feet above the surface. The water-bearing beds are thought to slope up into the terminal moraine to the south and the difference in elevation of the ground-water level in the water-bearing beds in the terminal moraine and at the various well sites accounts for the pressure. Most of the flowing-artesian wells occur in the wide valley of Holland River and its tributary. The possibilities of obtaining other flowing-artesian wells in this area appear to be very good. Wells drilled with the hope of encountering water under sufficient pressure to overflow the surface should be located at sites of low elevation, as it was noted that the water in a few wells in this area, situated at points of considerable elevation, did not flow although it did rise some distance in the wells.

Two flowing-artesian wells in lots 18 and 19, con. I, near Aurora, derive water from sand and gravel aquifers at 85, 100, and 160 feet. These aquifers are believed to be continuous with similar aquifers in King township to the west, but to be different from the aquifers yielding ground water to the flowing-artesian wells in the Newmarket area. Artesian pressures in these aquifers decreases towards higher ground to the south, and, in lot 15, water rises in non-flowing artesian wells only to within 6 feet of the surface.

Springs are fairly numerous throughout the township and at least 53 are being used for domestic or stock needs. They occur along drainage channels and at the bases of some hills. Water supplied by springs is abundant and of excellent quality. Numerous springs issue from the slope at the Stouffville water reservoir, and doubtless many not shown on the map occur in the township.

Community Supplies

Town of Aurora. The town of Aurora, population approximately 2,700, obtains its water supply from flowing-artesian wells. One flowing well is in Whitchurch township and the others, 7 in number, are in King township. The well in Whitchurch township, situated at the pumping station and standpipe, is 260 feet deep and derives water from sand and gravel at depths of 100 and 260 feet. The pressure is sufficient to raise the water 6 feet above the surface, and the water flows into a reservoir from where it is pumped into a standpipe. The flow from this well is approximately 50,000 gallons a day. Another reservoir of 35,000 gallons capacity on the west side of Yonge Street just south of the standpipe receives water from three flowing-artesian wells 91 to 98 feet deep. Water from four other flowing-artesian wells west of Yonge Street flows into a third reservoir of 11,000 gallons capacity. This water is obtained at depths of 119 to 140 feet and rises 6 to 8 feet above the surface. Water from all three reservoirs is pumped directly to the mains without processing. The daily consumption of water for Aurora is approximately 200,000 gallons. During 1936 some 77,000,000 gallons of water were obtained from the wells and there was a surplus of about 10,000,000 gallons.

Town of Newmarket. Newmarket, population 3,600, obtains its water supply from wells. Prior to 1937 the supply was derived from 3 flowing wells, 150, 200, and 300 feet deep. The water was pumped from a 100,000-gallon reservoir into a 175,000-gallon standpipe and thence to the mains. In 1937 a new well drilled by the International Water Supply Company came into use. Water was encountered in three horizons at depths of 90, 190, and 265 feet, but only that from the latter is being used. To remove impurities of sand, silt, iron, and natural gas, the water is first sprayed into a tank and then pumped through sand filters into the mains. Yield from this well is 140 gallons a minute.

Village of Stouffville. Stouffville, with a population of approximately 1,050, obtains its water supply from flowing-artesian wells and springs located in lot 9, con. VIII. Most of the water is derived from 8 flowing-artesian wells at depths of approximately 20 feet and is stored in two open cement and tile reservoirs of 250,000 and 300,000 gallons capacity. The water from a few springs is also diverted into the reservoirs. Water is piped by gravity to the town, which lies about 3 miles southeast of the reservoirs and 120 feet lower in elevation. It is used without purification. The average daily consumption is 75,000 gallons. The supply is sufficient for present needs.

During the summer of 1937 a test hole was drilled at the reservoirs in order to ascertain the possibilities of obtaining additional water below the level at which the present supply is derived. Water under artesian pressure was encountered in sand at about 20 feet. This was cased off and drilling continued to a total depth of 142 feet. At about 90 feet dry ground was encountered and at about 140 feet fine water-bearing sand. Water from this fine sand rose to within 40 or 50 feet of the surface, but in a period of 4 days sufficient sand had been drawn into the drill pipe to plug the lower 50 feet of the hole. The hole was then abandoned. Successful screening of the sand would be possible if it were necessary in the future to drill to this depth for water.

The water supplies of smaller communities throughout the township, such as Vandorf, Lemonville, Ringwood, Bethesda, Bloomington, Ballantrae, and Cedar Valley, are derived from privately owned wells. These wells are of various depths and obtain their water from the glacial drift. The supply is sufficient for local needs.

Analyses of Water Samples

One hundred and twenty-four samples of well waters from Whitchurch township were analysed for their mineral content in the laboratory of the Geological Survey of Canada. The samples were taken from depths of from 0 foot to 336 feet, and all are from glacial drift. Most of them were found to be suitable for domestic and farm use.

Amounts* of Dissolved Mineral Matter in Waters Collected in Whitchurch Township

Constituent	Water from glacial drift (124 analyses)		
	Maximum	Average	Minimum
Total dissolved solids	940	351	80
Silica (SiO_2)	30	15	2
Iron (Fe_2O_3) and alumina (Al_2O_3)	64	7	2
Calcium (Ca)	217	74	11
Magnesium (Mg)	34	19	3
Sodium (Na)	102	23	nil
Sulphate (SO_4)	149	41	8
Chloride (Cl)	156	22	3
Total hardness	800	296	45

*In parts per million.

Conclusions

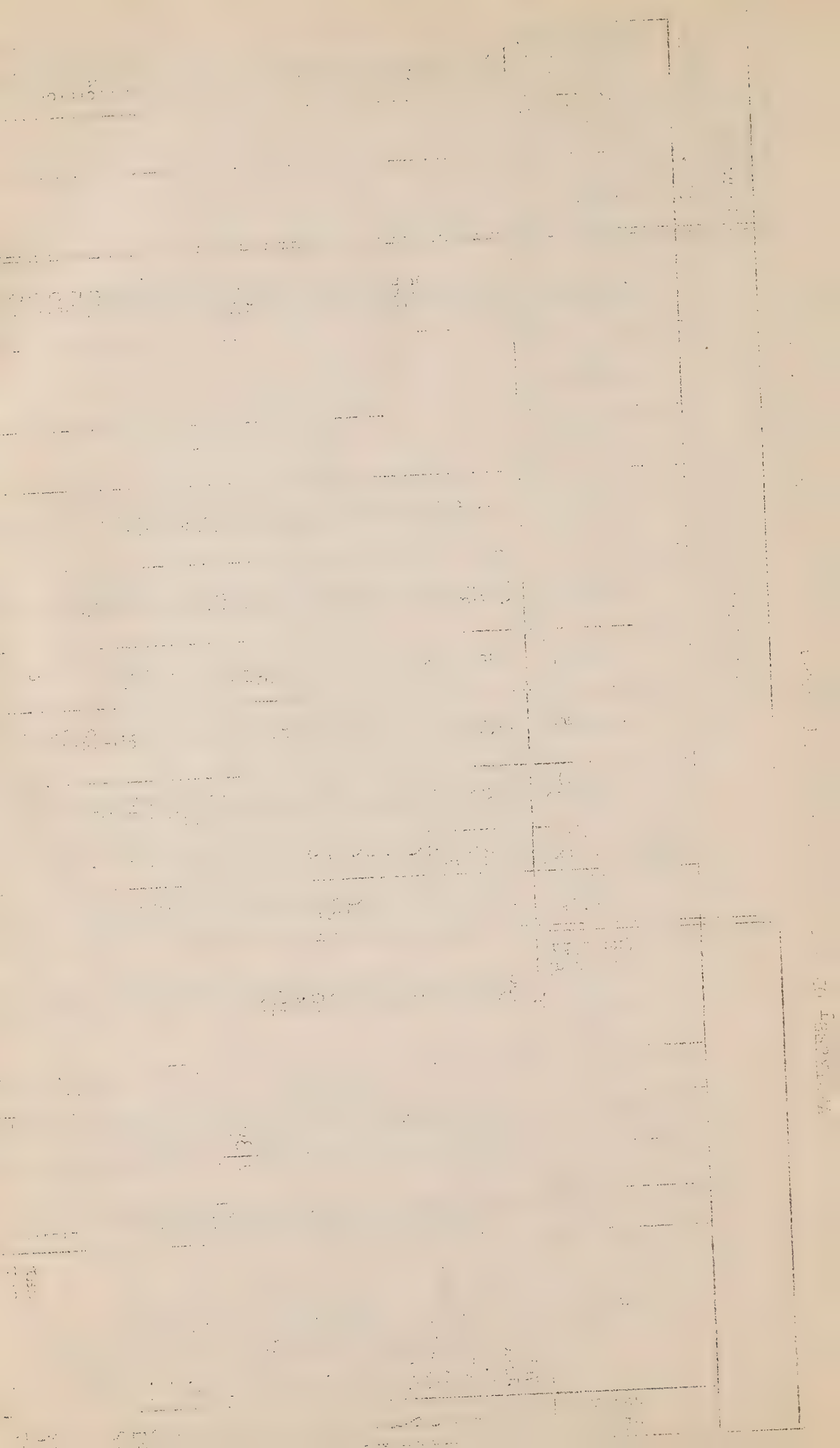
This investigation warrants the following conclusions:

1. In most parts of Whitchurch township ground-water supplies are fairly abundant. Most wells, except those in the northwestern corner of the township, supply ground water from depths of 80 feet or less.

2. Precipitation appears to be sufficient to furnish adequate supplies of ground water, but in times of drought, or during extended periods of decreased rainfall, consumption may be greater than recharge, resulting in a lowering of the water-table. Some wells go dry at such times, and it may be necessary to deepen them to ensure a permanent supply of water.
3. The quantity of ground water available from a well depends upon the porosity, thickness, and extent of the aquifer penetrated.
4. Aquifers in ground and terminal moraine areas are irregular lenses, pockets, and sheets of sand and/or gravel confined upon, within, or beneath relatively impervious clay or clay till.
5. Ground water is abundant and readily recoverable in the interlobate, or kame moraine, area in the central part of the township. However, the depth at which water may be reached varies considerably over this area.
6. Fine sand of some aquifers may plug wells and make them useless as a source of water. Screens have been used effectively to stop the flow of sand and ensure permanent supplies of water.
7. Flowing wells are numerous in two large areas within the township. Sand and gravel aquifers in those areas lie directly upon or beneath confining layers of clay or clay till. The aquifers have a fairly steep gradient up onto the terminal moraines, and the difference in elevation between the point where water enters the aquifer on the moraines and the point where it is released in the well forms sufficient hydrostatic pressure to cause the water to flow above the ground level.
8. Drilling into bedrock underlying the glacial drift is not advised. Water derived from this source will in all probability be too salty for domestic use.

ANALYSES¹ OF WELL WATERS FROM WHITCHURCH TOWNSHIP, YORK COUNTY, ONTARIO

Sample Number	Owner	Lot	Concession	Depth of well (Feet)	Aquitifer	Total dissolved solids (parts per million)	Constituents as Analysed (parts per million)										Hardness as CaCO ₃ (pts. per million)		
							Silica (SiO ₂)	Iron & Aluminum (Fe & Al)	Calcium (Ca)	Magnesium (Mg)	Alkalies (as Na)	Sulphate (SO ₄)	Chloride (Cl)	Nitrate (NO ₃)	Bicarbonate (HCO ₃)	Alkalinity (as CaCO ₃)	Ca hardness (as CaCO ₃)	Mg hardness (as CaCO ₃)	Total hardness (as CaCO ₃)
1	Webster	5	I	120	D.	300	22	8	79	26	5	65	7			220			260
2	Jones	5	I	180	D.	280	16	10	71	26	3	53	6			230			320
3	F. J. Berry	11	I	185	S.	320	4	4	86	26		34	5			285			320
4	Monkman	11	I	156	G.	340	14	12	93	23		41	6			290			360
5	E. M. Woods	14	I	50	D.	280	6	4	74	7	14	33	5			165			200
6	Jarvis	15	I	75	G.	220	10	6	72	5		33	5			155			220
7	Jarvis	15	I	75	D.	260	9	6	69	15	3	16	5			220			240
8	W. Wood	17	I	85	S.	280	14	6	80	20	2	36	3			245			260
9	Town of Aurora	19	I	260	S.G.	280	16	6	66	19		13	6			215			240
10	D. Morgan	21	I	55	D.	580	22	4	106	32	42	149	70			235			480
11	A. McElroy	23	I	40	D.	500	12	4	97	26	28	90	84			200			400
12	A. Robinson	24	I	50	D.	940	12	4	152	38	40	36	156			265			500
13	P. Smith	26	I	160	G.	180	10	4	40	16	30	35	7			185			240
14	Town of Newmarket	33	I	200	S.	340	16	2	31	17	56	15	86			180			240
15	"	33	I	300	G.	340	16	2	31	17	56	15	86			180			240
16	E. Fogal	34	I	15	G.	620	16	4	157	24	25	143	60	8		315			400
17	C. H. Lloyd	35	I	51	S.	740	10	4	129	33	28	110	52			260			520
18	E. Norris	35	I	180	G.	220	16	6	40	22	44	39	23	4		180			280
19	M. Cullen	35	I	336	G.	280	10	4	46	20	40	43	41	1		145			260
20	R. Gould	35	I	250	D.	240	10	4	37	22	40	38	37			180			240
21	W. Carlisle	35	I	115	G.	260	10	4	879	18		37	6			235			260
22	Langley	2	II	160	S.	260	10	6	71	22	8	41	6			210			220
23	Allen	5	II	100	S.G.	260	16	6	71	15	7	37	7			230			260
24	F. Bell	9	II	165	S.	320	10	6	86	26	7	49	12			270			230
25	Howard	15	II	90	S.	280	12	6	86	11	8	23	11			240			280
26	E. G. Pindar	21	II	28	S.	340	14	4	166	16		56	16			210			200
27	E. G. Pindar	21	II	125	G.	280	14	4	97	19		33	6			210			280



ANALYSES¹ OF WELL WATERS FROM WHITCHURCH TOWNSHIP, YORK COUNTY, ONTARIO

Sample Number	Owner	Lot	Concession	Depth of well (Feet)	Aquitifer	Total dissolved solids (parts per million)	Constituents as Analysed (parts per million)										Hardness as CaCO ₃ (pts. per million)		
							Silica (SiO ₂)	Iron & Aluminium (Fe) (Al)	Calcium (Ca)	Magnesium (Mg)	Alkalies (as Na)	Sulphate (SO ₄)	Chloride (Cl)	Nitrate (NO ₃)	Bicarbonate (HCO ₃)	Alkalinity (as CaCO ₃)	Ca hardness (as CaCO ₃)	Mg hardness (as CaCO ₃)	Total hardness (as CaCO ₃)
28	F. Graham	23	II	85	S.G.	340	16	4	72	30	3	56	17			230			380
29	R. Playter	27	II	45	D.	560	12	6	103	31		115	51	40		245			500
30	A.P. Williamson	27	II	76	D.	180	12	2	17	10	42	15	10			145			115
31	A. Starr	32	II	150	D.	340	12	2	86	24	3	77	16			220			280
32	A. E. Starr	32	II	52	D.	260	20	4	60	23	9	15	3			245			250
33	F. Baillie	33	II	125	D.	240	18	4	51	23	31	34	10	4		240			300
34	Smith	7	III		D.	300	10	2	79	22	5	45	7			245			280
35	C. Billing	12	III		D.	280	12	6	86	24	1	49	13			250			240
36	Vandort	17	III	140	D.	180	10	16	23	20	13	20	4			140			150
37	A. McDonald	17	III	125	D.	380	12	2	66	25	18	31	7			265			300
38	J. Petch	21	III	63	D.	720	14	2	160	34		72	56			280			550
39	R. Willis	24	III	2	D.	80	4	6	11	3	13	13	3			50			45
40	N. Kay	25	III	110	D.	180	14	2	31	30		5	5			150			260
41	H. Osely	27	III	110	D.	320	8	2	77	24	10	54	5			250			300
42	C. J. Toole	30	III	Spr.	D.	280	14	4	49	22		26	4			180			280
43	A.H. Flintoff	31	III	125	D.	260	12	2	54	25	10	13	5			240			250
44	School	31	III	116	D.	260	10	2	54	24	8	33	3			215			260
45	A. Starr	32	III	60	D.	260	12	2	66	21	9	52	5			210			260
46	W. Duffy	35	III	127	D.	380	10	10	72	26	14	66	20			220			400
47	C.C. Thompson	2	IV	107	D.	300	12	12	66	16	24	30	13			235			240
48	L. Brillinger	9	IV	43	D.	300	8	44	34	10		30	12			225			300
49	Preston	13	IV	100	D.	300	14	9	71	24	21	49	7			260			280
50	Radmore	13	IV	155	D.	400	6	8	60	6		15	7			370			320
51	Preston	13	IV	29	D.	420	12		33	33	25	49	41			260			300
52	Preston	13	IV		D.	340	10	8	37	28	2	8	6			315			320
53	Van Nostrand	15	IV	120	D.	280	28	4	64	31		41	9			230			300
54	M. Yake	20	IV	160	D.	680	22		114	31		61	68	5		225			650

ANALYSES¹ OF WELL WATERS FROM WHITCHURCH TOWNSHIP, YORK COUNTY, ONTARIO

Sample Number	Owner	Lot	Concession	Depth of well (Feet)	Aquifer	Total dissolved solids (parts per million)	Constituents as Analysed (parts per million)										Hardness as CaCO ₃ (pts. per million)		
							Silica (SiO ₂)	Iron & Aluminum (Fe & Al)	Calcium (Ca)	Magnesium (Mg)	Alkalies (as Na)	Sulphate (SO ₄)	Chloride (Cl)	Nitrate (NO ₃)	Bicarbonate (HCO ₃)	Alkalinity (as CaCO ₃)	Ca hardness (as CaCO ₃)	Mg hardness (as CaCO ₃)	Total hardness (as CaCO ₃)
55	H. A. Switzer	21	IV	93	D.	340	8	2	74	23	1	36	8			235			280
56	C.W. Bostwick	24	IV	30	D.	320	8	2	77	24	10	54	5			250			300
57	C. Greenwood	26	IV	50	D.	600	16	4	129	32		100	30			270			425
58	B. Dike	28	IV	200	D.	180	12	2	20	9		23	3			130			150
59	F.S. Sheridan	33	IV	45	D.	500	16	2	114	26		100	25			245			400
60	E. Clubine	1	IV	17	D.	500	6	34	37	30		36	35			265			460
61	Bolender	7	V	110	D.	280	4	36	43	15		28	11			235			280
62	F. Allen	10	V	145	D.	260	4	48	29	11	8	25	10			230			240
63	W. Winterstein	10	V	195	D.	200	10	6	54	9		15	5			170			200
64	W. Winterstein	10	V	20	D.	620	6	6	31	17		25	38			325			440
65	W.R. Chapman	13	V	52	D.	400	8	6	114	15		26	20			280			320
66	W.R. Chapman	13	V	152	D.	320	54	64	34	18		25	6			235			300
67	W.R. Clarke	13	V	150	D.	340	6	6	29	11	21	48	8			265			360
68	Fines	17	V	31	D.	580	10	2	114	11		26	15	50		170			300
69	H. McClune	30	V	120	D.	220	18	4	57	14		107	3			290			400
70	Sinclair	30	V	16	D.	520	18	2	129	18			15			185			300
71	Estate																		
72	S. Hope	32	V	44	D.	260	30	2	49	21		18	9			190			260
73	F. Stockley	5	V	87	D.	340	18	62	29	19		79	27			205			260
74	Wells	10	VII	90	D.	260	8	4	86	7		26	6			230			280
75	S. Castle	14	VII	114	D.	280	8	4	83	15		31	6			220			260
76	P. Wright	21	VII	21	D.	260	12	4	72	6	31	30	8			190			240
77	P. Kaufman	32	VII	32	D.	240	12	2	66	8	13	39	3			200			200
78	Timbers	4	VII	4	D.	200	20	4	57	19	2	20	3			185			220
79	Hall	10	VII	92	D.	220	10	8	69	10	5	25	10			215			220
	S. Sibley	12	VII	20	D.	220	10	2	77	13	5	36	5						

ANALYSES¹ OF WELL WATERS FROM WHITCHURCH TOWNSHIP, YORK COUNTY, ONTARIO

Sample Number	Owner	Lot	Concession	Depth of well (Feet)	Aquifer	Total dissolved solids (parts per million)	Constituents as Analysed (parts per million)										Hardness as CaCO ₃ (pts. per million)		
							Silica (SiO ₂)	Iron & Aluminum (Fe & Al)	Calcium (Ca)	Magnesium (Mg)	Alkalis (as Na)	Sulphate (SO ₄)	Chloride (Cl)	Nitrate (NO ₃)	Bicarbonate (HCO ₃)	Alkalinity (as CaCO ₃)	Ca hardness (as CaCO ₃)	Mg hardness (as CaCO ₃)	Total hardness (as CaCO ₃)
80	B.W. Flewell	14	VII	118	D.	280	10	4	72	18		44	6			195			280
81	J. Jordan	21	VII	20	D.	340	10	4	83	7		31	9			230			300
82	A. Nelson	29	VII	10	D.	980	12	6	217	10		80	90			150			800
83	F. Naylor	30	VII	84	D.	220	10	4	66	3	5	25	7			215			220
84	T.G. McPherson	35	VII	115	D.	240	10	8	80	13	4	36	8			205			240
85	Stouffer	3	VIII	95	D.	240	12	4	51	20	14	23	8			220			240
86	Mortson	5	VIII	100	D.	260	10	4	72	17	6	30	7			230			260
87	F. Lennon	9	VIII	14	D.	300	8	4	89	14		33	11			220			300
88	E. Lennon	9	VIII	18	D.	340	8	4	92	10		34	13			220			320
89	B. Barnes	10	VIII	85	D.	340	12	4	83	23	2	23	8	22		255			320
90	N. Rae	12	VIII	131	D.	340	16	4	97	15	8	33	9	14		220			340
91	G. Talbot	13	VIII	115	D.	440	12	4	103	20		41	15	22		275			340
92	O. Tyanmar	13	VIII	40	D.	540	14	2	100	15	12	43	15	73		215			340
93	W.J. Brown	14	VIII	147	D.	300	10	4	86	13	6	30	8	15		240			280
94	W.A. Fockler	14	VIII	150	D.	320	8	2	89	15		31	5			230			320
95	J. Windsor	16	VIII	65	D.	220	10	6	77	5		20	15	50		180			220
96	J. Windsor	16	VIII	14	D.	540	14	4	126	10		44	15			255			340
97	W. Coupland	18	VIII	50	D.	240	12	4	83	5	4	28	4			205			240
98	G. E. Davies	18	VIII	20	D.	280	12	2	74	8		33	5			180			280
99	J. Nesbitt	20	VIII	58	D.	300	8	2	74	8	1	33	3			210			300
100	S.H. Wallwork	23	VIII	104	D.	240	10	4	83	10	14	38	10			205			240
101	F. Lagter	26	VIII	81	D.	300	12	4	86	11	6	26	9			230			280
102	E.A. Storrey	11	IX	42	D.	520	18	2	114	17	6	44	21	55		225			360
103	A. Smith	14	IX	159	D.	500	8	4	77	12	4	30	4			215			300
104	H. Mitchell	16	IX	115	D.	320	12	4	80	15	8	38	7			230			300
105	C. Phillips	17	IX	65	D.	340	8	4	83	16	23	44	6			270			260
106	O. Degger	18	IX	90	D.	280	10	4	74	18	12	33	6			245			260

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ANALYSES¹ OF WELL WATERS FROM WHITCHURCH TOWNSHIP, YORK COUNTY, ONTARIO

Constituents as Analysed (parts per million)										Hardness as CaCO ₃ (pts. per million)									
Sample Number	Owner	Lot	Concession	Depth of well (Feet)	* Aquifer	Total dissolved solids (parts per million)	Silica	Iron & Aluminum	Calcium	Magnesium	Alkalies	Sulphate	Chloride	Nitrate	Bicarbonate	Alkalinity	Ca hardness (as CaCO ₃)	Mg hardness (as CaCO ₃)	Total hardness (as CaCO ₃)
							(SiO ₂)	(Fe) (Al)	(Ca)	(Mg)	(as Na)	(SO ₄)	(Cl)	(NO ₃)	(HCO ₃)	(as CaCO ₃)			
107	Forfar	21	IX	56	D.	220	10	4	92	11	6	33	17			210			220
108	G. Walker	26	IX	46	D.	240	12	6	80	11	5	36	7			210			240
109	T. Moorehead	35	IX	100	D.	240	22	4	69	18	3	34	5			210			240
110	Aurora Tap Water					320	18	4	77	22		26	4			240			300
111	Newmarket Tap Water					460	14	20	57	24	95	33	90			285			280
112	Reesor Lake					120	2	6	26	4	20	18	7			95			80
				*	C.- G.- S.- D.-	Clay Gravel Sand Drift													

¹Analyses by F. J. Fraser and A. H. Dray; Geological Survey of Canada

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Summary of Wells and Springs

Number and character of wells and springs	Concessions										Total No. in township	Percentage of total
	I	II	III	IV	V	VI	VII	VIII	IX	X		
Total number	255	156	148	138	111	102	129	117	112	12	1343	64.0
Dug wells	175	89	109	113	79	51	81	63	58	16	850	0.6
Bored wells	0	0	0	1	3	2	1	0	1	0	3	30.7
Drilled wells	64	59	35	20	25	38	41	11	47	3	413	0.9
Driven wells	8	0	0	0	0	0	0	1	1	0	10	3.9
Springs	8	8	4	4	4	11	6	3	5	0	53	
Wells 0-40 feet deep	170	80	87	103	33	56	72	90	59	11	818	60.9
Wells 41-80 feet deep	23	21	34	15	8	24	28	40	38	0	237	17.9
Wells 81-120 feet deep	20	22	13	7	8	11	13	12	9	0	122	9.0
Wells 121-160 feet deep	20	26	10	3	4	0	3	5	5	0	76	5.6
Wells 161-200 feet deep	8	2	2	2	1	0	0	1	1	0	17	1.2
Wells over 200 feet deep	4	1	0	1	0	0	0	0	0	0	6	0.5
Wells depth unknown	10	4	2	7	7	11	8	18	0	0	67	4.9
Wells that yield hard water	242	144	138	132	104	90	117	165	113	18	1253	93.3
Wells that yield soft water	1	0	0	2	1	0	2	0	1	0	7	0.5
Wells that yield salty water	0	0	0	0	0	0	0	0	0	0	0	
Wells with aquifer in sand	103	47	60	40	52	54	71	105	78	5	615	45.7
Wells with aquifer in gravel	54	37	21	18	4	22	13	17	10	3	204	15.2
Wells with aquifer in clay	22	27	26	32	24	10	10	17	9	1	178	13.2
Wells with aquifer in drift	63	41	32	47	29	14	27	29	12	7	306	22.9
Wells with aquifer in bedrock	0	0	0	0	0	0	0	0	0	0	0	
Wells with aquifer unknown	4	0	3	1	0	1	1	0	0	0	10	0.9
Flowing wells	11	21	4	2	10	23	21	4	5	1	112	8.4
Non-flowing wells	232	125	134	132	95	67	98	151	98	17	1148	85.4
Wells with permanent supply	204	114	112	110	85	83	109	153	96	16	1082	80.4
Wells with non-permanent supply	39	30	26	24	20	7	10	12	8	2	176	13.2
Dry holes	4	4	6	0	2	1	4	5	3	1	30	2.2
Wells not used	30	16	13	9	5	5	11	13	9	4	116	8.6

← Cardinal



MAP 1

MARIATOWN

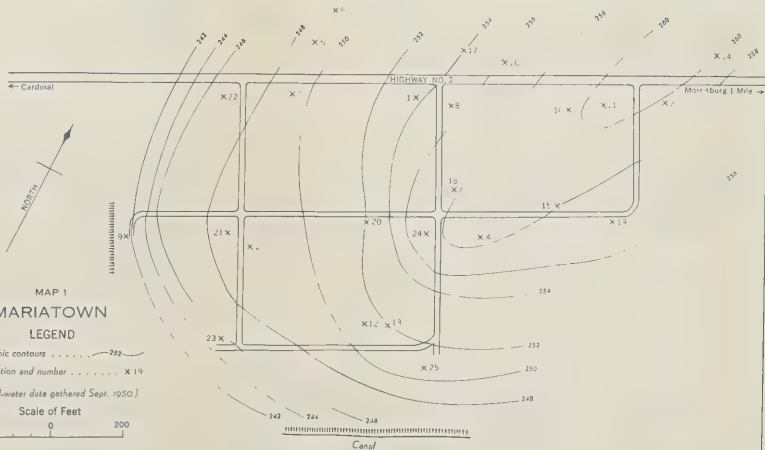
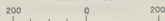
LEGEND

Topographic contours 252

Well, location and number X 19

(Ground-water data gathered Sept. 1950)

Scale of Feet



MAP 2
WILLIAMSBURG
LEGEND

Topographic contours 272

Water-table contours 268

Well, location and number X38

(Ground-water data gathered Sept. 1950)

Scale of Feet



FIGURE 1
MAP SHOWING TYPES OF OVERBURDEN AND BEDROCK FORMATIONS

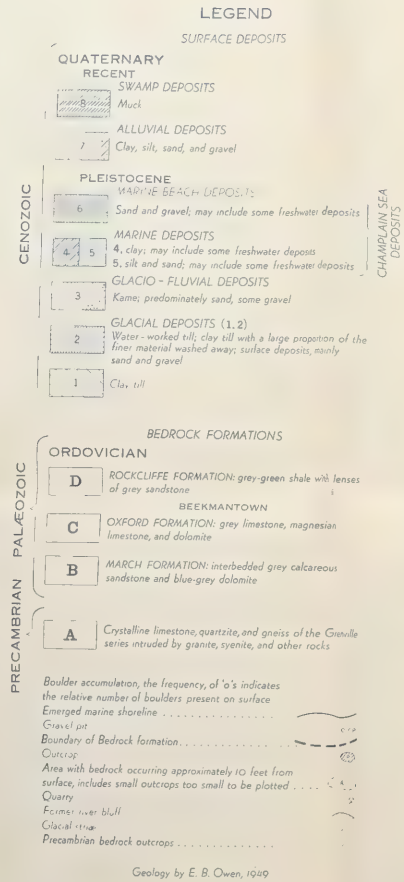
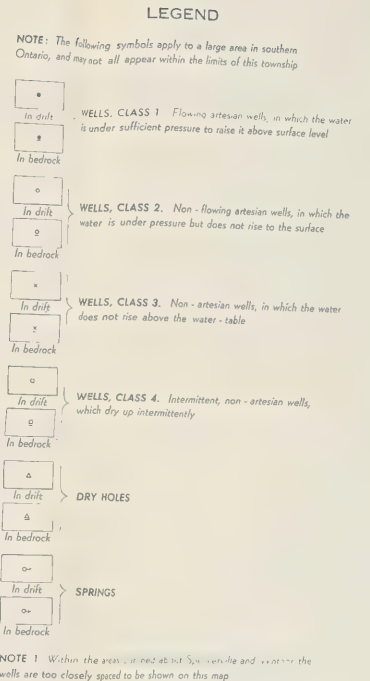
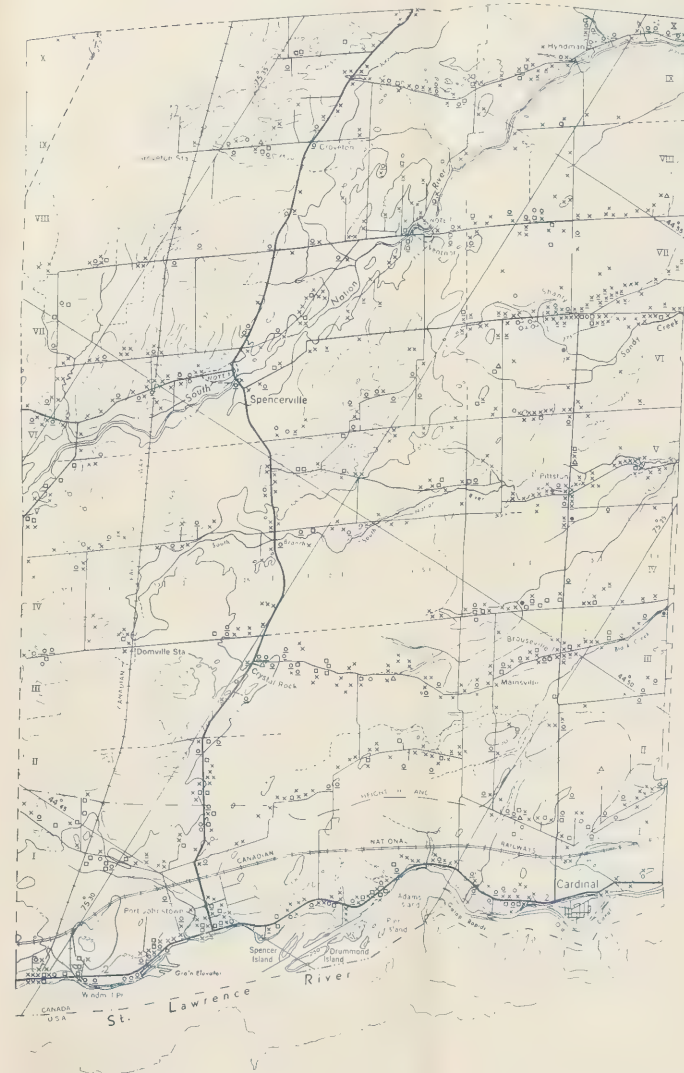
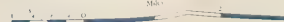


FIGURE 2
MAP SHOWING TOPOGRAPHY AND LOCATION AND TYPE OF WELLS



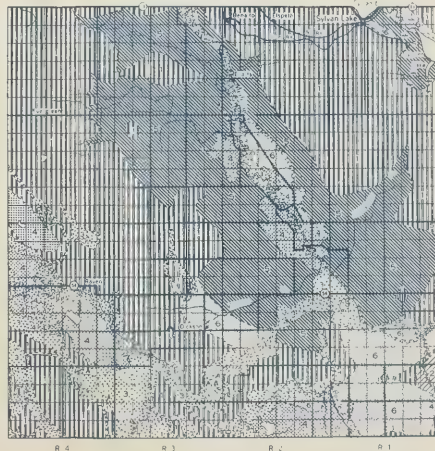
EDWARDSBURGH TOWNSHIP
GRENVILLE COUNTY
ONTARIO

Scale: One Inch to One Mile = $\frac{1}{63,360}$



G 3730-1

FIGURE 1
MAP SHOWING SURFACE DEPOSITS



LEGEND

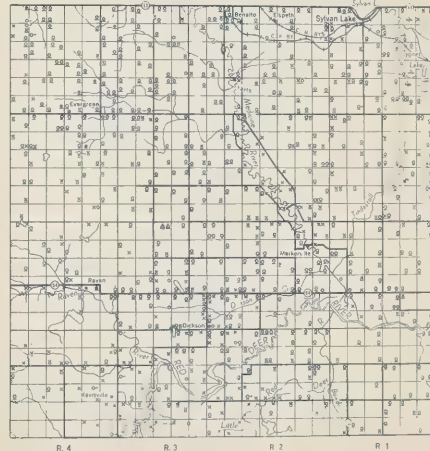
SURFICIAL MATERIAL

QUATERNARY

PLEISTOCENE AND RECENT

- GLACIAL-LAKE SAND
Includes sand deposited along streams draining the lakes, in places reworked by wind
- GLACIAL-LAKE SILT AND CLAY
- DUNE SAND
Wind-blown lacustrine and alluvial sand
- ALLUVIUM
Stream-deposited gravel, sand, silt, clay; includes patches of till, and some glacial-outwash gravel. The sand and silt commonly reworked by wind
- END MORAINE
Till
- GROUND MORAINE
Till with lenses of sand and gravel
- Geological boundary (approximate)

FIGURE 2
MAP SHOWING TOPOGRAPHY AND LOCATION AND TYPES OF WELLS



LEGEND

- Wells, Class 1. Flowing artesian wells, in which the water is under sufficient pressure to rise to the surface
- Wells, Class 2. Non-flowing artesian wells, in which the water is under pressure but does not rise to the surface
- Wells, Class 3. Non-artesian wells, in which the water does not rise above the water-table
- DRY HOLES
- SPRINGS

NOTE: A short dash under any symbol indicates that the well is in bedrock

Road
Railway
Marsh

TOWNSHIPS 35-38, RANGES 1-4

WEST OF FIFTH MERIDIAN

ALBERTA

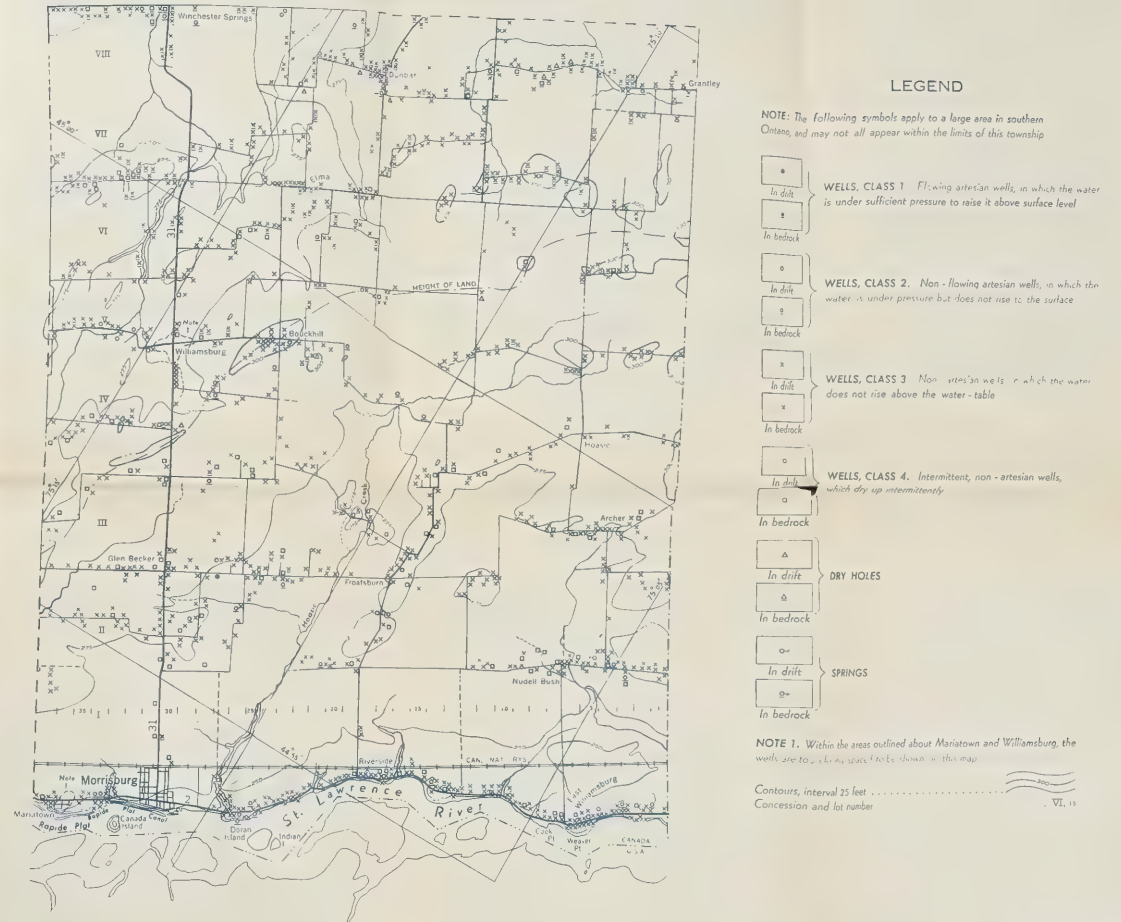
Scale, 1 Inch to 4 Miles



FIGURE 1
MAP SHOWING SURFACE DEPOSITS



FIGURE 2
MAP SHOWING TOPOGRAPHY, AND LOCATION AND TYPES OF WELLS

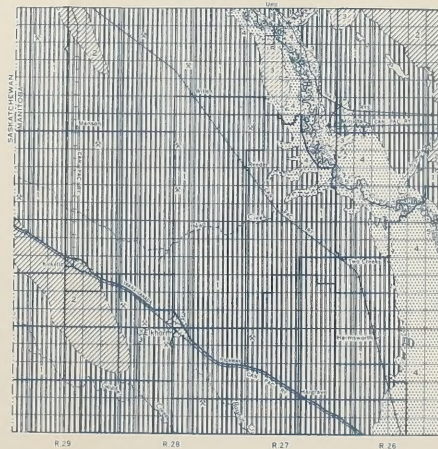


WILLIAMSBURGH TOWNSHIP
DUNDAS COUNTY
ONTARIO

Scale: One Inch to One Mile = $\frac{1}{63,360}$

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FIGURE 1
MAP SHOWING TYPES OF OVERBURDEN



LEGEND

SURFACE MATERIAL

QUATERNARY

RECENT

ALLUVIUM
Clay, silt, sand, and gravel

PLEISTOCENE

WATER-WORKED TILL
Shallow water-laid deposits of silt, sand, and gravel

OUTWASH GRAVEL

END MORAINE
Till, sand, and gravel, surface rolling and irregular

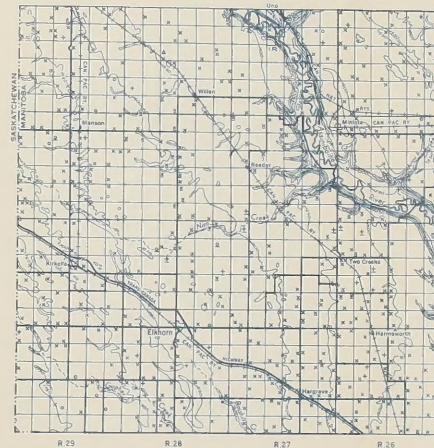
GROUND MORAINE
Till with lenses of sand and gravel; surface uneven

Gravel pit, in use or abandoned
Geological boundary (approximate)

BEDROCK FORMATIONS

The Upper Cretaceous, Riding Mountain formation of grey and greenish, siliceous shale underlies all of this area

FIGURE 2
MAP SHOWING TOPOGRAPHY AND LOCATION AND TYPES OF WELLS



LEGEND

- WELL CLASS 2. Sub-artesian; the water is under pressure but does not rise above the ground surface
- WELL CLASS 3. Non-artesian; the water does not rise above the level of the water table
- Well that produces water, but for which information is scant or lacking
- DRY HOLE

NOTE: A short dash under any symbol indicates that the well is in bedrock

Road
Railway
Contours (interval 50 feet)

TOWNSHIPS 11-14, RANGES 26-29

WEST OF PRINCIPAL MERIDIAN

MANITOBA

Scale: 1 inch to 4 Miles

